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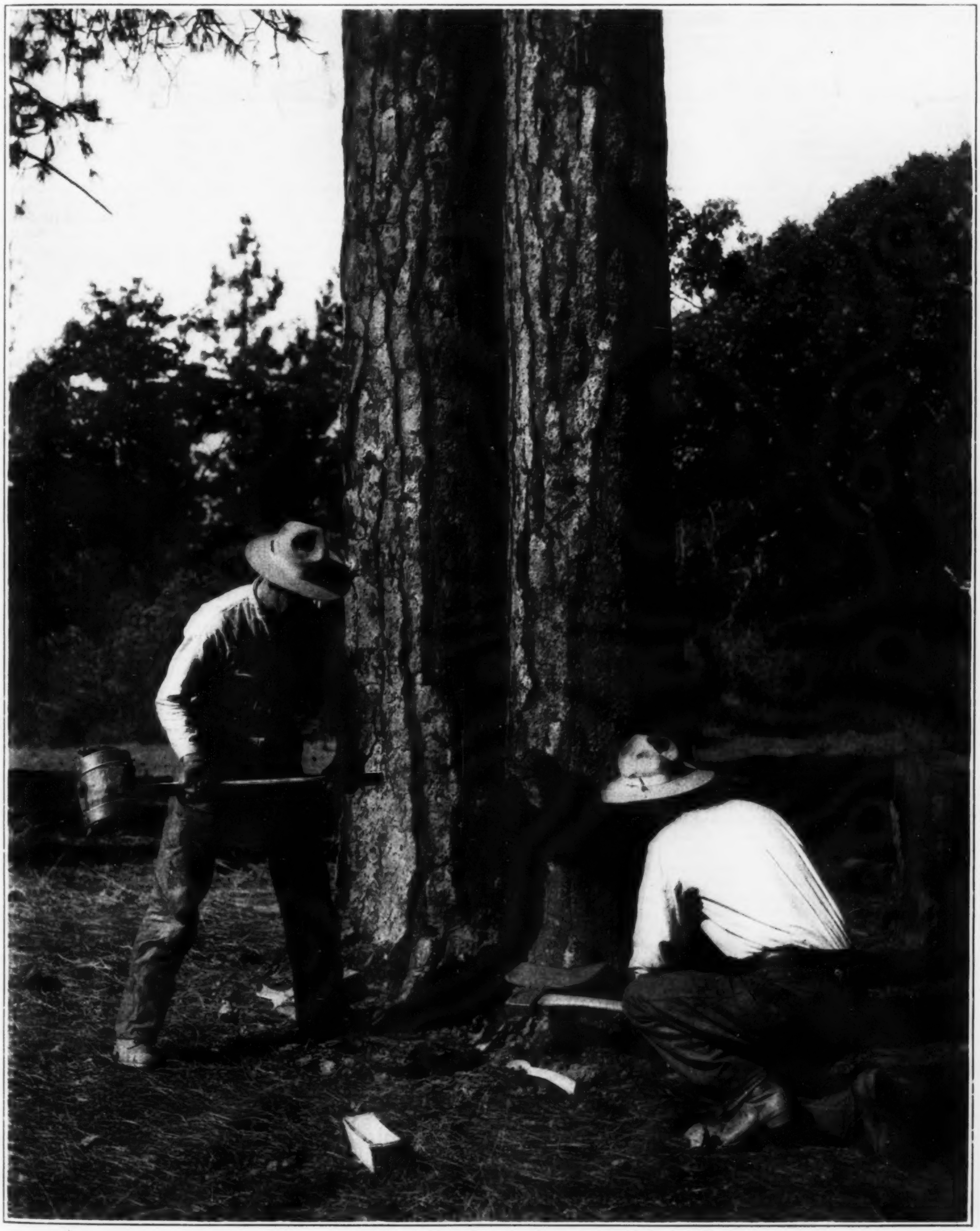


Grooving a turpentine pine for setting the apron

GATHERING TURPENTINE—[See page 312]

X-Rays*

An Historical Review of Their Discovery, and Modern Methods of Employment

By William J. Hancock, Hon. Radiographer, Perth Public Hospital, Western Australia, Hon. Lieut. R. A. M. C.

Early in the year 1896, just over twenty years ago, a sensational announcement appeared in the newspapers that a "new light" had been discovered, by means of which photographs could be taken through the human body. When the details were published it was found that this description was not quite correct, but nevertheless it showed that Prof. Röntgen, of Wurtsburg, had made a discovery of great importance, and which had subsequently proved to be of great assistance to the physician and surgeon, besides leading, somewhat indirectly, to the discovery of radio-activity, and radium itself, by Madame Curie, about two years later.

Before discussing Prof. Röntgen's discovery, it might be well if we briefly review the previous work in this field of research, up to the end of 1895.

We are all, I think, familiar with the appearance of the electric discharge through the air, and the noisy and wirey appearance of the spark between the terminals of an induction coil; if, however, we send the current of electricity between two metal electrodes fused into the ends of a glass tube, from which the air is gradually withdrawn by a pump, we notice that instead of the noisy, disruptive sparking, that a steady and faintly banded illumination fills the tube, depending on the extent of the exhaustion, and the residual gases.

The-well known Geissler tubes in their great variety of beautiful forms are examples of electric discharge at medium vacuum.

With a high degree of vacuum, and such brilliant experimentalists as Sir William Crookes, new and strange phenomena were observed and instead of the continuous illumination, dark and colored bands or striae fills the tube between the two electrodes. The positive pole or anode appears surrounded by a purple glow and from the negative electrode, or cathode, a luminous beam extended in straight lines to the farther end of the tube, and striking the inner walls of the tube, produced fluorescense on the glass.

This latter phenomenon is beautifully shown in a pear shaped tube designed by Crookes, in which a hinged maltese cross of aluminium is fitted so that the cross acts as a shield to intercept the rays. If I now turn on the current, you will notice that the part of the glass unprotected by the cross became brilliantly fluorescent, while the portion that is shielded, appeared as a faintly luminous shadow of the maltese cross, showing that the aluminium had not entirely stopped the cathode stream. Now, on tilting the cross down, the shadow now became more brilliant than the surrounding portion, thus demonstrating that the glass becomes fatigued, as a result of the cathode bombardment. If I bring a magnet close to the tube, you will notice that the cathode stream is bent from the straight path. This tube is also interesting as it was a tube of similar design which Prof. Röntgen used in his experiments.

The color of the fluorescense depends mainly on the composition of the glass; a pale blue fluorescense is shown by lead glass, reddish-yellow by lithium while soda or potash glass exhibit a yellow green fluorescense, and substances such as shells, marble and precious stones, become brilliantly fluorescent under the bombardment of the cathode rays; chemical effects are produced, such as the darkening of photographic plates, and minature windmills with mica vanes rotated at a high speed, thus illustrating the conversion of electrical energy of the cathode stream into heat, chemical energy and mechanical work.

The cathode stream was found to consist of flying particles of matter, shot from the cathode in straight lines, and high velocity, and deflected by a magnet, and in all these respects differing from ordinary light, or ultra-violet rays, which have been shown to be indulating waves or vibrations of varying wave length. "Radient matter" was the name originally given by Crookes to these flying particles, but later they have been identified as electrons. Sir J. J. Thompson has calculated their speed at 124 miles per second. It is therefore, not surprising that when these flying particles collide with an object, they set the molecules of the object vibrating, and cause fluorescense, nor that they should heat an object placed in the focus. It has been found that the heat produced is proportional to the charge of rushing electrons, and therefore, proportionate to the current, and not to the square of the current as in the passage of electricity through a solid conductor, and it is also interesting to note that the energy appears to flow from the negative toward the positive pole of the electric current, or in the reverse direction assumed in general practice, and which was originally assigned by Volta as the direction of flow, but Volta had not, I presume, considered hydrogen to be an electro-positive metal.

The cathode stream of electrons can be deflected from the straight line by a magnet as shown in a previous experiment, and it was also found by Crookes that the stream of particles could pass through certain substances more freely than through others; aluminium appeared to be more transparent than platinum or copper, and that this property was shown to vary with the density of the material. This led Professor Lenard to attempt to get the cathode stream into the air by designing a vacuum tube with an aluminium window at the end opposite the cathode. The window being of extremely thin aluminium foil, and of very small area, by these means, Lenard was able to obtain a faint bluish defused glow to about two inches from the window, and to produce fluorescense in certain substances, and to affect photographic plates if brought very close to the window, but instead of the straight beam which is characteristic of the cathode stream, only the faint defused glow was observed, and it was evident that it was not the cathode stream that had emerged; it was a new phenomenon, to which I will refer later.

We have now reviewed very briefly, some of the main experiments, and what was known of a newly discovered form of matter, up to the end of 1895. It would be impossible in one evening to go into details, or even to examine step by step, the progress in this field of research, but Lenard's aluminium window experiments, and Crookes' pear shaped tube are especially interesting in view of Prof. Röntgen's discovery.

In discussing the experiments up to this date, we have no mention of the generation of rays outside the tube, excepting perhaps, Lenard's experiment; it was therefore, startling that in the autumn of 1895, Prof. Röntgen of Wurtsburg, Bavaria, should have discovered, almost accidentally, the rays which now bear his name. During the course of a search for invisible rays he used a pear shaped tube similar to Crookes high vacuum cross-tube. This tube was enclosed in black paper, so as to cut off any illumination of the tube itself, and when the tube was in operation, he was greatly surprised to find a paper coated with barium-platino-cyanide lying on a table a few feet away, light up brilliantly—the black paper cover over the tube precluded any possibility of the effect being due to ultra-violet or invisible light, and it was obvious that the radiation came from the vacuum tube itself, and Röntgen found that objects placed between the tube and the fluorescent screen cast shadows on the screen, and in this way he was able to trace back these new radiations to their source, which proved to be the area where the cathode stream strikes the glass walls of the tube. Further investigation proved that whenever the cathode stream impacts on matter, X-rays are produced, and here was the startling feature of these new radiations, that they had the extraordinary ability to penetrate substances opaque to light.

Prof. Röntgen in a long and exhaustive paper read before the Physical Society of Wurtsburg in December, 1895, describes how he used a tube similar to the Crookes vacuum tube enclosed in a black cover and compared the new radiation with ordinary light, ultra-violet and cathode rays, and describes how the screen of barium platino-cyanide lit up brilliantly, and as to why these new rays have been called X-rays. I will quote from a note to his paper. He states: "For brevity's sake I should like to use the expression rays, and to distinguish them from other rays, I will call them X-rays." In this paper he describes various experiments, and discusses their property of penetration, fluorescense, chemical action, effect of the magnetic field, and other scientific data, and I will quote again from his paper, the only remark he made which alluded to the one fact that perhaps, in the public mind, eclipsed all the other scientific aspects of his paper. It is as follows: "If the hand is held between the discharge tube and the screen, the dark shadows of the bones are visible within the slightly darker shadow of the hand." From perhaps a scientific point of view, he had added flesh and bones to the list of materials more or less transparent to the new rays, but when it became known that the rays could pass through the hand and show clearly the bones, the rays were so to speak, taken out of the Physical Laboratory, and used without loss of time by the physician and surgeon, who did not worry how they were produced, but found them of immense use in their work.

One might now ask how it was that with all the brilliant experimenters at work exploring this field of research, that the X-rays should have, after all, been discovered in an accidental manner. I think there are two reasons; first, that the phenomenon was not anticipated, and no doubt many vacuum tubes (as proved afterwards), gave out X-rays without these radiations being recognized, and we now see how close Crookes and Lenard were to the discovery, indeed the bluish glow at Lenard's window were X-rays, but too small in quantity to assert their startling ability. But, perhaps, the immediate discovery was due to the fact that Crookes and other workers were using lead glass, while apparently Röntgen used a tube made apparently identical with Crookes tube, but probably unknown to Röntgen, made of glass free from lead, and it was not until after Röntgen accidently saw his fluorescent screen lit up, that it was realized that lead glass did not generate X-rays, while lead-free glass produced them freely. To illustrate this interesting point, I have a tube similar to Röntgen's tube only that the body is made of lead glass, while one end is made of lead-free glass, and you will notice when I turn on the current, the bluish fluorescense of the body portion, and the apple green color of the end of the tube; the former emits no X-rays or very little, while the apple-green end emits X-rays in abundance.

In the original X-ray tube, the cathode consisted of a flat disk at one end with anode on one side and about the middle of the tube; this form, however, gave unsatisfactory results, the X-ray shadows appearing blurred. A great improvement in the design of the tube was made by Prof. Herbert Jackson of King's college. In this tube, now universally used, the cathode is concave and the cathode stream is focussed on the anode or what is now called the anti-cathode or target, and which consists of a plate or disk of dense metal placed at an angle of about 45 degrees to the cathode. The cathode stream, striking the anti-cathode is deflected at right angles to the side of the tube and from its glass surface, X-rays are given off. The generally accepted theory is that in the impact of the cathode stream carrying electrons at very high velocity against the glass walls of the tube, the energy of motion of the flying particles is transformed into a type of vibrations to which Röntgen gave the name X-rays, somewhat as bullets or projectiles driven at high speed against armour plate transforms their energy or motion into vibrations of light, heat and sound.

The general form of X-ray tube has been little altered, since Prof. Jackson's original design, aluminium is usually used at the cathode, while platinum and other metals, and lately tungsten, has been used at the target or anti-cathode. The original anode has been reintroduced, as it is found to steady the stream and assist it in reducing the ill-effect of reverse current from the induction coil. When the tube is new, it gives a beautiful apple-green fluorescense, and in this condition the tube is called "soft," but after working for some time the cathode stream finds greater difficulty in passing through the vacuous space and the emission of the X-rays becomes reduced, and higher electric pressure is required to generate the rays. After operating the tube for some time, the glass gradually assumes a purple tinge and becomes darkened, this effect being probably due to volatilization of the electrodes and disposition of material on the inner walls of the glass. To provide a means of adjusting the resistance of the tube several arrangements have been devised; one form consists of a small alternate discharge tube with an electrode of mica or asbestos and communicating with the large bulb; by passing current through this attachment, small quantities of residual gas are given off, which lowers the resistance of the tube. Another form consists of a fine palladium tube, about one inch long, closed at one end, the open end being fused into the X-ray bulb. On heating the closed end of the tube with a spirit lamp, air is admitted through the walls of the palladium tube, as palladium becomes porous at red heat. Another mode of improving the working of a "hard" tube is to heat the tube in an oven, and it is also found that several months' rest will often bring back a tube to its normal condition, though none of these devices are quite satisfactory and ultimately the tube becomes unworkable.

Recently a new tube has been designed by Coolidge—the cathode is formed of a flat tungsten wire spiral

*A paper read before the Royal Society of Western Australia, October 12, 1916.

surrounded by a focussing tube of molybdenum, as the vacuum is many times higher than the ordinary X-ray tube the cathode has to be heated by a separate current before the current will pass. This tube is more effective and easier controlled than the ordinary tube but is much more costly at present. The X-rays differ from ordinary light in many respects. They are invisible to the eye, but can penetrate substances opaque to light, and have the property of forming a path of conduction of electricity, and this effect is shown by placing a charged electroscope in the neighborhood of the X-rays tube, and when I turn on the current to the tube, you will notice that the leaves of the electroscope at once collapse, showing that the insulation of the air has broken down and a path of conduction has been formed by the X-rays and this effect is known as ionisation, and good insulators such as paraffin, guttapercha, india rubber, practically cease to be insulators under the X-ray beam.

The property of the rays to cause fluorescense in certain substances, such as barium platio-cyanide, and to effect the photographic plates is made use of in examination of injuries to the body, or in searching for foreign bodies, in the following manner:

The portion of the body to be examined is placed between the x-ray tube and the screen or plate, thus the rays in passing through the body are intercepted to a greater extent by metallic substances and the bones, and least by the flesh, thus the shadow of the bones or foreign body appear darker than the flesh, on the screen. The movement of joints can be seen, or the beating of the heart followed, and as wood and bandages are transparent to the rays, a broken bone can be examined through the clothes, splints, or bandages, or the canvas stretcher, which in some cases of great advantage to the unfortunate patient.

As the shadow on the screen or plate shows everything on the same plane, it is not possible to estimate the depth of, say a bullet, as compared to the adjoining bones, and as it is of great importance to the surgeon to know the depth of a foreign body from the surface, various methods have therefore, been devised to locate the foreign body—they are all founded on the principle of triangulation, and I will describe and illustrate with the actual apparatus I have used in the Perth Hospital for some years, and now at the No. 8 Military Base Hospital at Fremantle, for the location of bullets and shrapnel in our returned soldiers.

I will first describe the methods of localization by the photographic plate and cross-thread measurement, and secondly by the fluorescent screen.

By the first method, let us take a simple example, say a bullet in the chest. The patient lies on the table and the photographic plate is enclosed in a light tight paper envelope and placed below him, the X-ray tube being vertically above. An exposure is made; the tube is then moved along the table, say 10 centimeters, and a second exposure made—the height of the tube above the patient and above the plate is measured for each exposure and when the plate is developed, two images of the bullet are seen, although the plate is blurred by being exposed twice. So long as the images of the bullet can be clearly seen, this is all that is necessary, and by simple calculation the depth of the bullet can be found.

To save calculations or for checking the cross thread method of measuring the depth of the foreign body is as follows: the plate after development is placed on a table above which is supported a bar with two sliders, and adjusted so that each slider is in a position corresponding to the position occupied by the center of the target for each exposure, and from each slider a thread is stretched to each image or shadow of the bullet on the plate, and as the stretched threads represent the rays, the point where they cross represents the position of the bullet and the distance from the front or back of the patient can be at once measured, from the data taken.

The fluorescent screen method is to place the X-ray bulb below the patient—who lies on a canvas or light wooden top of a table—the fluorescent screen is placed on a support, which can be moved along of the table and as close as possible to the patient. The tube and screen are now adjusted so that, when the tube is working the X-rays pass vertically through the bullet and show its shadow on the fluorescent screen. As the vertical distance between the target of the tube and screen is fixed and known, it is obvious that if the tube is moved horizontally, it will cause the shadow of the bullet to move in the opposite direction on the screen, and the distance through which the shadow is moved on the screen, relative to the distance moved by the tube, is a measure of the depth of the bullet.

Both these methods give satisfactory results, but the former has the advantage of being a record, and of great use for comparisons of subsequent examinations.

The X-rays are found to possess beneficial results in cases of some skin and other diseases—unfortunately very serious and painful damage can be caused by improper or prolonged exposure to the rays, so that great care has to be used so as to avoid damage to healthy tissues, and ill-effects frequently do not appear for some time after excessive exposure.

The ability of X-rays to pass through opaque objects such as wood, leather, canvas is made use of for inspection of boxes and packages for customs and other purposes, and also for inspection of manufactured articles when it is undesirable or impossible to make an ordinary examination without destroying or damaging the article, and to illustrate the value of X-rays examinations, I will refer to two cases I was consulted about some time ago.

A certain make of time fuse for firing explosives in the mines was found to be uncertain as to its rate of burning. I examined by X-rays and fluorescent screen a few lengths of the fuse to detect possible irregularities in the filling of the powder. I also took some skiagrams showing the powder in the fuse and by special arrangement I was able to observe on the screen the burning of the powder inside the fuse. Although the examination was satisfactory I feel sure that with further experiments better results could be obtained.

The other instance was in reference to an alleged electric "Water Finder" in which the movement of a magnetized needle was supposed to indicate the presence of water underground. A well finished brass bound mahogany case and carefully sealed, enclosed the mysterious appliance, but an X-ray examination revealed its interior arrangements. The skiagrams I took with 30-second exposure gave excellent detail information which it would be otherwise impossible to obtain without breaking the seals and opening the box.

The current required for the X-ray tube is of high voltage, as produced by an induction coil, or, in large installations as in the Perth Public Hospital, by means of a rotary converter and condenser, and a step up oil transformer, with special means for rectifying the current from the transformer so that instead of the usual sine wave type of alternations, which would be detrimental to the X-ray tube, a pulsating uni-directional current is produced. The voltage varies with the size of the generating apparatus from about 60,000 volts for 3-inch spark, to 150,000 volts for 10 inches and higher. The current, however, is small and is measured in milliamperes.

It would be impossible to discuss in a short paper, the various theories in connection with the cathode stream of the flying electrons, or the generation of X-rays or as to some recent investigations as to the deflection of X-ray by certain crystals, but I feel sure that you will agree with me that this is but another instance, and a startling one, of the high order and the immense value to humanity, to industry, and to the state, of the research work carried out in the scientific laboratories.

The Future of Selenium*

By Fournier d'Albe

The principal phenomena presented by selenium and its potential applications may be thus stated: The action of light upon selenium manifests itself in two different manners:

1. The resistance of a piece of selenium diminishes under the influence of light;

2. When one of the electrodes of a battery cell [élément de pile] is composed of selenium an electromotor force is produced in this cell element as soon as light falls upon the selenium, and is maintained as long as it remains illuminated.

There are numerous allotropic varieties of selenium, of which the principal three are as follows:

1. Vitreous selenium, which is a very efficacious insulator.

2. Crystalline selenium, endowed with average conductibility and insensitive to light.

3. Another form of crystalline selenium, not quite so good a conductor as the preceding but sensitive to light. This variation, which is obtained by maintaining vitreous selenium for several hours at a temperature of 210° C., is the only one which is of importance from the photo-electric point of view.

The action of light upon selenium is attributed to a phenomenon of ionization; the light liberates additional electrons which transport the current. When the light is suppressed the ions recombine; the larger the number of liberated ions contained by the selenium, the greater the speed of the recombination. Consequently this recombination takes place at first rapidly, then more slowly, and the resistance correspondingly increases.

For feeble illuminations it has been demonstrated:

1. That the conductibility conferred on selenium by a prolonged exposure to light is proportional to the square root of the intensity of the illumination; in other words, it is inversely proportional to the distance between the selenium and the source of light.

2. That the conductibility conferred temporarily by an instantaneous exposure to light is proportional to the incident energy.

The preceding laws are valuable only when the illuminations are inferior to a candle-meter. In the case of strong illuminations the phenomenon is complicated by a relatively slow action of the light, whose mechanism is poorly elucidated, which tends to accelerate the recombination of the ions. Its effect is to reduce the action of the light until it approximates the cube root of the illumination.

We can gain an idea of the size of the current furnished by selenium by recalling that an illumination of 1,000 lux, for an electro-motor force of 1 volt, furnishes a current of one milliampere per square centimeter of the sensitive surface. With higher voltages the effect is proportionally more intense, but we can hardly go higher than 50 volts; beyond that the selenium becomes heated and loses its conductivity. With feebler illuminations the utilizable effect is comparatively greater, by reason of the law of the square root. Thus, in reducing the light to one ten-thousandth of the value indicated above, *i. e.*, 0.1 lux, we reduce the current of one milliampere only to 0.1 milliampere.

Hence, selenium is specially suited for revealing very feeble illuminations. Its use in stellar radiometry has already given interesting results. In carefully studying the curve of light of Algol by means of a cell of selenium placed at the principal focus of a telescope with an aperture of 30 centimeters, Stebbins was able to prove that the obscure companion of Algol has a feeble luminosity of its own.

A great number of applications of selenium have been proposed. Let us enumerate then briefly:

a. Electric photometry.—Absolute photometry by means of selenium has not been realized, but the devices which have been constructed permit us to make photometric comparisons with precision and rapidity. The difficulty lies in the very marked predominance exerted by the visible red at the end of the spectrum.

b. Lighthouses and luminous buoys which can be automatically lighted and extinguished by selenium.—With respect to this achievement we are still in a state of experiment.

c. Transmission of words.—The photophone of Graham Bell constitutes the first solution of the problem of wireless telephony, which has been since attacked from other directions.

d. Transmission of drawings by telegraph.—The solution of the problem was first attempted by the use of selenium, but afterwards this metal was replaced by bichromated gelatine.

e. Vision by wire.—Selenium has been selected to assist in resolving this captivating problem, but up to the present the high cost of the necessary installations, and the difficulty of reproduction at the receiving station, have constituted a check.

f. Reading by ear.—The problem of substituting audition for vision in case of the loss of the latter sense, has been attacked in England by M. Fournier d'Albe (1912) and in America by Brown (1915). The results obtained demonstrate that the employment of selenium and of a sensitive telephone permit reading by ear, even when the impression is slight.

It must be confessed that many attempts to employ selenium in different ways have not been successful. The reason for this is to be sought, thinks M. d'Albe, in the property it shares with sulfur and oxygen, its close relatives in all classifications of the metalloids, of combining readily with metals: it furnishes, more or less easily, selenides with all the metals, even with gold and with platinum (it is perhaps aluminum for which it has least affinity). In electric circuits in which selenium is employed, these selenides are formed at the point of contact of the selenium with the other conductors in the circuit; they seriously hinder the action of the light and even finally annihilate it. The remedy consists in making the ends of the conductors, which are generally metallic, of carbon. This remedy has been employed recently in various forms, and the results obtained permit us to look forward with more confidence to future applications of selenium.

From a purely theoretic point of view M. d'Albe indicates how we may hope to solve by selenium a physical problem of the first importance relative to the theory of the "quanta." This theory claims that luminous emission is effected by "quanta," extremely minute entities, but distinct. These quanta are so small that when the eye receives the light of the least luminous of the visible stars it absorbs about 360 quanta per second. Their number, in this case, is about twenty times too great for them to be perceived as distinct flashes. But any receiver whose sensitiveness sufficiently surpasses that of the eye would permit us to determine whether the structure of light is discontinuous or not. It is easily comprehensible how great would be the interest attaching to such an experiment, were it realizable, from the point of view of the theory of the "quanta."

*The following abstract of M. d'Albe's article in *Scientia* is reprinted from the *Rev. Gen. des Sc.* (Paris).

Glass Grinding and Polishing*

How the Surface Prepared for Optical Purposes Is Formed

By James Weir French, B.Sc.

THAT the polished surface of a piece of glass differs in its physical condition from the original underlying material has been recorded by Lord Rayleigh and subsequent observers.

Sir George T. Beilby, in his series of published papers dealing with the subject of the polished surfaces of metals, has explained how the surface layer is formed. According to this investigator the forces exercised in the rubbing of the surface overcome the crystallic and cohesive forces binding together the surface molecules, which rearrange themselves uniformly under the action of the surface tension forces.

In this way a surface which scatters light, owing to the presence of masses of molecules whose irregularities are great compared with the wave length of light, is converted into a continuous reflecting surface, the irregularities of which are less than a wave length.

When the surface of a piece of metal is scratched a groove is formed as the result of the tearing away of masses of crystals and partly by the swaging of the material. When such a scratched metal surface is polished the grooves become covered over with a continuous surface flow layer and disappear. If the surface is removed by etching the grooves reappear.

The cohesion of the surface flow layer is such that considerable areas can be bridged over. Sir George Beilby originally supposed that the groove became filled with débris, which acted as a support for the surface layer, but in a paper,[1] illustrated by beautiful colored photographs, he has demonstrated that no such supporting débris is necessary. One of these photographs shows a surface pit covered over by a continuous layer, and the absence of supporting débris is evidenced by the variation of the color of the layer, due to retransmission of light, reflected from the internal surfaces of the pit.

*Transactions of the Optical Society (London).

[1]Proceedings of the Royal Society, A. Vol. 89, 1914.

When a polished glass surface is etched by means of hydrofluoric acid, either in the liquid or the gaseous state, or by means of caustic soda, the surface appears covered with innumerable scratches. It has been assumed accordingly that glass behaves in the same general manner as metal when its surface is polished.

It is the purpose of this article to show that the conditions determining the behavior of glass are very different in certain essential respects from those determining the behavior of metals.

A simple groove or pit that is comparatively deep with respect to its width can be formed on most metal surfaces as the result of the removal of masses of crystals, or by compression or swaging of the material. This is not possible in the case of a vitreous substance such as unworked glass, in which conchoidal fracture is a characteristic. When an unpolished glass surface is scratched numerous conchoidal splinters are removed, and under the miscroscope such a scratch appears as an irregular band of conchoidal concavities of considerable width compared with its depth.

Fig. 1 is a photo-micrograph, magnification 250 diameters, of the fine emery-ground glass surface immediately before the first polishing operation with rouge is commenced. It will be seen that there is no evidence of any definite scratches, such as reappear when the polished surface layer is etched. The tops of the ridges have been focused upon.

If scratches in the glass material were covered over by a surface layer, it is to be expected that fine particles of foreign material or débris would be included, but an examination of many thousands of finished glass surfaces has failed to reveal any such included matter.

Attempts have been made by the author to include foreign matter in the irregularities of the glass surface and in fine grooves or sleeks of the polished surface, which will be referred to later, but without success. The finest deposit of silver in the hollows of a ground glass surface all disappears during the polishing process. The inclusion of foreign matter in fine grooves in polished surfaces has proved to be equally impossible.

Air bells afford a simple means of examining the question of the covering over of pits by the surface layer. For experimental purposes there was made a special piece of glass containing a great number of airbells, varying in diameter from about 0.002 to 0.01 inch. The surface when polished showed pits of numerous sizes. Airbells that were just broken into became filled with rouge and could be easily observed. Very minute holes were formed in the case of the smallest airbells that were just broken into, and an examination of the orifices showed no signs of any continuous bridging over as the result of polishing. In the case of the larger airbells the orifices were comparatively large and more irregular.

It would appear that the cohesion of the silicates constituting glass is too small to permit of any continuous bridging over effect such as is observable in the case of metals in which the cohesion is evidently very much greater.

Notwithstanding the above observation, it is an easily demonstrable fact already well known in most optical factories that when a polished glass surface is lightly etched innumerable fine, clean scratches are exposed. The explanation would appear to be that the essentially fine scratches in question exist only in the surface flow layer of the polished glass. If the scratch penetrates the surface layer its outline becomes irregular, due to the conchoidal splintering of the material.

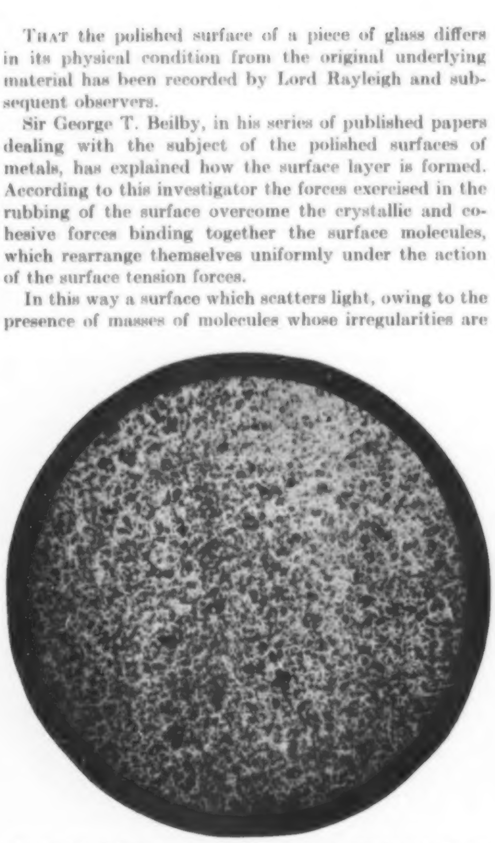


Fig. 1—Magnification 250 diams. Tops of ridges in focus

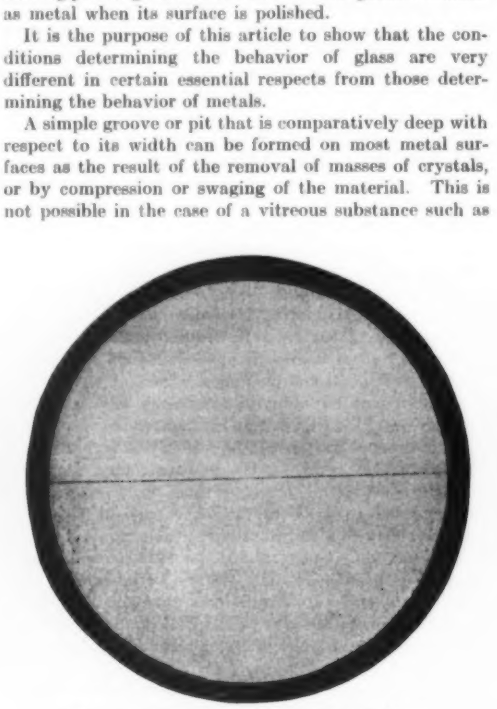


Fig 2—A "Sleek", Magnification 230 diams.

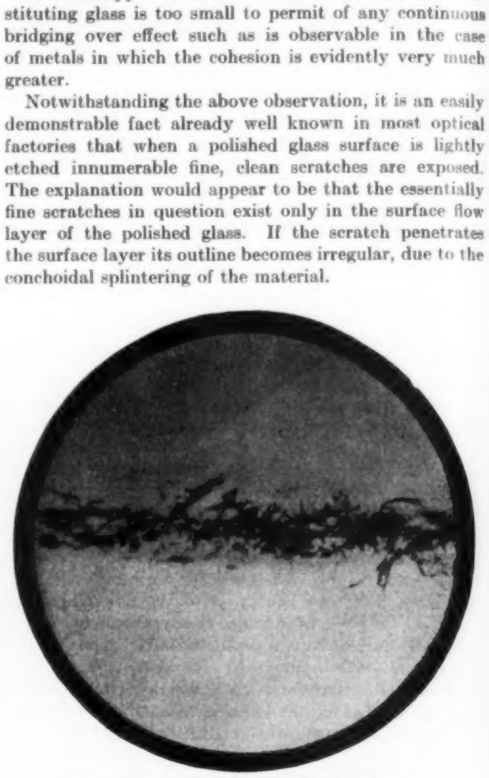


Fig. 3—A "Cut", Magnification 50 diams.

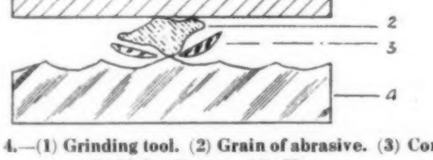


Fig. 4.—(1) Grinding tool. (2) Grain of abrasive. (3) Conchoidal splinters. (4) Glass

In the workshop two kinds of scratches are recognized; one exhibiting irregular fractures is called a *cut*, and the other, having clean, well defined edges, is called a *sleek*. The term "scratch" is rarely used except in a very general sense. For purposes of explanation, the original glass will be called Alpha glass, and the modified material, such as the surface layer, will be called Beta glass. The result of the present investigation would seem to indicate that a cut is a scratch in the Alpha glass and that a sleek is a scratch in the Beta glass.

From a comparison of Fig. 2, which represents a typical sleek magnified 230 fold, and Fig. 3, which is a photograph of a cut magnified 50 fold, it will be seen that the characteristic differences are very definite. Material has evidently been ploughed uniformly from a surface layer of a comparatively amorphous substance in the formation of the sleek, whereas material has been burst irregularly from a more brittle substance in the formation of the cut.

Fig. 2 is a very perfect example of a sleek. It was obtained, however, from the workshop in the ordinary course of manufacture.

The cut Fig. 3 was produced by drawing a hard steel point over the finished glass surface.

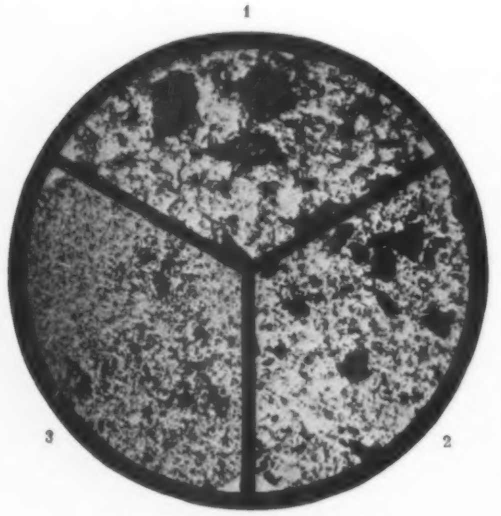


Fig. 5—Magnification 50 diams.

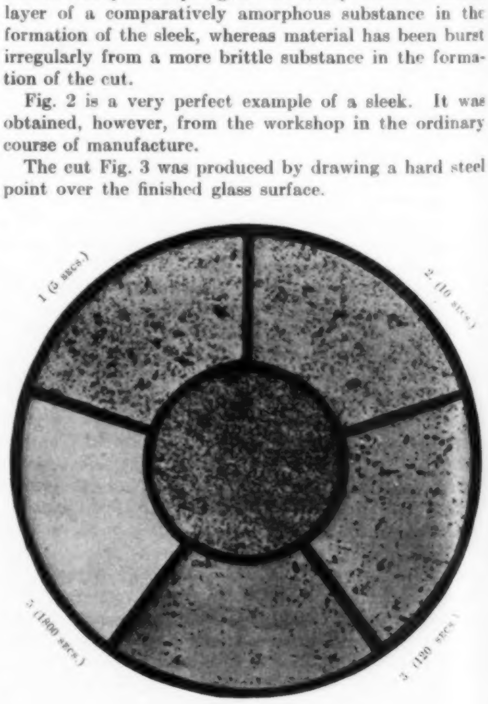


Fig. 6—Magnification 215 diams.

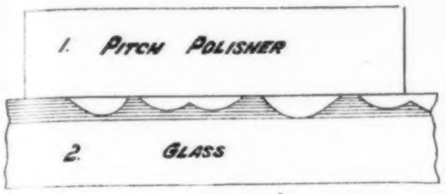


Fig. 7

It is suggested that the stages in the production of a polished glass surface are as follows:

In Fig. 4 (1) is the metal grinding tool, usually fine grained cast iron; (2) is a hard grain of the loose abrasive, such as carborundum; and (4) is the glass being ground. The pressure of (2) is localized at the points of contact of the grain and the glass, with the result that conchoidal splinters are burst off. Portions of these splinters can be recognized in the débris under the microscope. Under the rubbing action of the tool (1) the grain (2) also tears its way through the glass, but the general result is the same production of splinters.

When the abrasive is coarse the pressure of the tool is transmitted to the glass by a comparatively small number of grains and the pressure at the individual points of contact is correspondingly great, with the result that large splinters are produced.

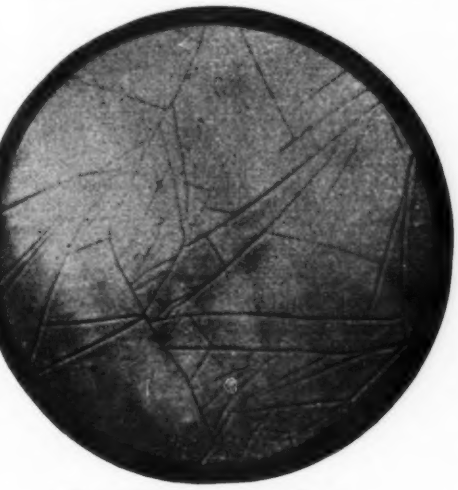


Fig. 9—Magnification 100 diams.

When the abrasive is fine the pressure of the tool is transmitted through a large number of points and the forces are smaller and less material is removed.

If the abrasive is hard and unyielding the intensity of the pressure at the points of contact will be greater than in the case of a softer material, the points of which will yield and distribute the load.

From Fig. 5 a comparative idea will be obtained of the abrasive effects produced by various grades of abrasives. All three photomicrographs represent the same piece of glass, and in all cases the magnification is 50 diameters. The black masses are the abrasive materials placed on the surfaces.

Sector 1 shows the abrasive effect of carborundum that has passed through a sieve of 80 meshes per inch. Sector 2 shows the effect of emery that has passed through a sieve of 160 meshes per inch. Sector 3 shows the abrasive effect of emery that has not settled in water during a time of 40 minutes. Fig. 1, already referred to, is the same surface, sector 3, magnified 250 diameters. It shows the stage before the polishing, or, as it is called, the finishing process, is commenced.

In all these rough grinding or smoothing operations with hard abrasives, such as carborundum or emery, the effects are the same throughout. They differ only in degree.

When a splinter is formed the forces at the surface of fracture are probably so great as to overcome the cohesive and crystallic forces. The surface molecules accordingly arrange themselves, under the action of surface tension, and form glazed surfaces. This explanation of the glazed surface of fracture is only advanced as being a possible one. The action probably resembles the fire glazing of glass in which the cohesion of the surface molecules is overcome by heat instead of mechanically. Where two such surfaces intersect the molecules forming the edge rearrange themselves under the action of surface tension and the ridge becomes rounded. Under the microscope such rounded edges have a characteristic green appearance.

The network of rounded edges is clearly indicated in Fig. 1, a close examination of which will help one to realize how readily the molecules of glass when disturbed rearrange themselves in a continuous surface form.

Where two ridges intersect there is produced a spot having a continuous reflecting surface. These ridges and spots are the initial stage of the polished surface.

It is important to note that the removal of material and the polishing of the surface occur together even when using the roughest abrasive. The two actions occur together throughout the whole process until the final surface has been produced.

In the early operation the removal of material is very great in comparison with the polishing produced, and in the final stages the removal of material is comparatively small, although it always occurs.

If a surface smoothed with fine abrasive be examined by oblique reflection it will be seen that, although the greater part of the light is scattered, a considerable quantity is reflected. Even a rough ground surface, if carefully viewed, exhibits some reflecting power.

It is remarkable how easily, by the exercise of mechanical force, such as rubbing with a piece of wood, with the finger-nail, or even continued rubbing with the finger, the cohesion of the glass molecules can be overcome to such an extent that they can rearrange themselves to form portions of a continuous reflecting surface layer. Something akin to liquefaction may be said to take place, the molecules when disturbed having the power of rearranging themselves, just as in the case of the fire glazing of a surface as the result of thermal agitation of the molecules.

If this effect of mechanical agitation is clearly kept in mind, the next stage in the polishing of a surface will be the more readily understood.

When the polishing tool, which frequently consists of a flat layer of pitch on the face of a metal plate, is rubbed on the glass surface, the portion of glass in immediate contact becomes liquefied, as already explained, to a depth of about 1/4000th to 1/5000th inch (about 1/200th millimeter), and this liquefied surface becomes broken up and detached during the rubbing process. New material is thus exposed to the liquefying action, and is in turn removed. This process repeats itself, *and a perfect surface is only obtained by the removal of material beyond the bottom of the hollows produced in the glass surface during the earlier smoothing process.*

It will be realized how important it is in practical work that in the smoothing process there should be produced no hollows of unusual depth, since to remove such a hollow it is necessary to polish away the whole surface right down to the bottom of the pit.

This is illustrated by the series of photomicrographs, Fig. 6, which show the results of polishing a smoothed piece of crown glass for various periods. A very hard cloth polisher with rouge as a polishing medium was employed, special care being taken in the regulation of the conditions of working. In all cases the magnification is 250 diameters, and as nearly as possible the same portion of the surface is represented in all the photographs.

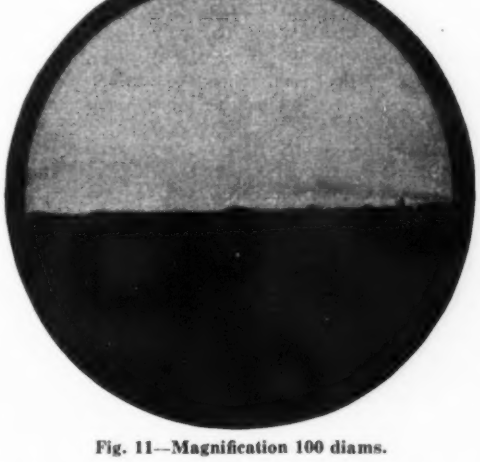


Fig. 11—Magnification 100 diams.

The central portion represents the smoothed surface ground with 40 minute emery on a flat cast-iron tool. Sector 1 shows the result of 5 seconds' polishing; sector 2 shows the result of 10 seconds' polishing; sector 3 shows the result of 120 seconds' polishing; sector 4 shows the result of 300 seconds' polishing; sector 5 shows the result of 1,800 seconds' polishing.

In sectors 1 and 2 the amount of scattered light is so great, owing to the large proportion of light, scattering hollows that a good contrast under the microscope is not readily obtainable. In sectors 3, 4 and 5 the proportion of polished surfaces to hollows is so great that the desired contrast by suitable illumination is obtainable.

Similar series of photographs have been taken for various types of hard and soft glasses with various types of polishers and polishing media. In all cases the general characteristics are the same, and in no case is there any evidence of hollows or pits in the original Alpha glass being filled or covered over.

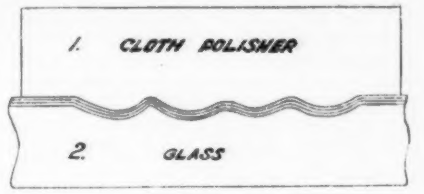


Fig. 8

There is, of course, a well recognized difference between a soft cloth polished surface and a pitch polished surface. In the instance illustrated above, the cloth was of a very special kind hardly distinguishable in its effects from pitch.

Although the action of a soft cloth polisher is fundamentally the same as that of a pitch polisher, it is interesting from the practical point of view to consider the effects produced by the two materials.

In Fig. 7, 1 is the pitch polisher, the surface of which is flat and comparatively unyielding, and 2 is the glass. Under the action of the polisher successive flat layers of the glass are liquefied, broken up, and removed, as is indicated by the parallel horizontal lines.

Fig. 10—Actual size

In Fig. 8, the soft cloth polisher comes into contact with the surfaces of the hollows, and the layers—indicated as before by the contour lines—are no longer flat, but follow approximately the original surface.

It is well known in the workshop that the irregularities of the surface can never be polished flat by means of a soft cloth polisher. Sinuosities having glazed surfaces always remain.

A surface that is not completely polished exhibits what is technically known as greyness when the polisher is a pitch one. The greyness is caused by scattered light from the hollows. If, at an earlier stage, say before sector 3 of Fig. 6, a soft cloth polisher had been used, the bottoms of the pits would have become glazed and at the later pitch stage the greyness would not have been readily observable. The pits, however, would still exist and would detract from the optical perfection of the surface. To remove them it would be necessary to remove the material beyond the bottom of the hollows with a pitch or equivalent tool.

It is commonly thought that a cloth polisher hastens the action. In reality a cloth polisher removes material more slowly than a pitch polisher. It only apparently hastens the action by masking the greyness and by creating the impression that the surface is finished before it actually is.

From the truly optical point of view it might even be preferable to leave the surface grey than to disguise the defects.

There are many kinds of optical work in which it is quite permissible to mask the greyness, in which case the use of cloth of varying hardness is advantageous.

For the production of a high quality optical surface in which masking of the greyness is not permissible, the use of a soft cloth polisher before the pitch polisher offers no advantages. It really only lengthens the time of polishing.

Quantities of the surface material removed by polishing have been collected and examined under the microscope, but a satisfactory microphotograph suitable for reproduction has not been obtained owing to the want of contrast in the specimens.

The material was collected in the process of polishing

the surface of a very obtuse angled prism by means of a pitch and rouge polisher. The material removed from the flat surface being polished accumulated in the form of a hard, cement-like layer on the inclined surface which was not in contact with the polisher.

When the rouge is dissolved out of the hard cement, an extremely fine, snow-like powder of glass remains. Under the miscroscope this glass presents a complex appearance. There are numerous rounded grains of glass which it is interesting to note closely resemble in size and form the grains of the polishing medium. Indeed, so close is the resemblance that the glass grains can only be distinguished from the grains of rouge by the sparkling appearance of the former under suitable illumination.

There also appear flat patches apparently consisting of a large number of grains welded together. Whether separate grains have actually welded themselves together to form the patch or whether it is a portion of the surface layer that has been peeled off is not clear. The former assumption implies welding properties for which the author can offer no definite evidence. It is true that two flat polished surfaces of glass can be pressed into such intimate contact as to suggest a welding of the contact layers. When the two pieces of glass have different coefficients of expansion, they can be separated by the application of heat and the contact surfaces in general present their original appearance. When the pieces have the same expansion, to separate them may not be easy. If such surfaces could be separated it would be interesting to know if the contact layers have been actually welded.

In support of the latter assumption that the patch is a portion of the original surface layer of Beta glass, there is the common experience of the workshop that portions of the surface layer do peel off. Peeling of the surface is quite a well-known occurrence in the process of polishing glass.

By a fortunate chance the author is in possession of additional evidence in support of the statement that the polished surface consists of a definite layer of Beta glass having physical properties differing from the original Alpha glass and having a considerable thickness of about eight wave lengths.

A block of crown glass having polished and smoothed faces was heated to a temperature which appears to have been below the softening point of the Alpha glass and just above that of the Beta glass.

The smoothed unpolished surface remained unaltered, whereas the polished surface exhibited a network of grooves, due apparently to the softening and contraction of the Beta layer, in which there must evidently have been a considerable tension.

Fig. 9 is a photo-micrograph of the grooved surface, the magnification being 100 diams. The grooving has all the well known characteristics of the crazed surface of glazed pottery where the physical properties of the glaze differ from those of the underlying material.

For comparison a photograph of a typical crazed pottery surface is represented in Fig. 10.

In Fig. 9 the uniform width of the individual lines suggests a uniform thickness of the layer.

It will be noticed also in both specimens that the grooves do not cross one another. A patch evidently cracks across as the result of contraction, thus forming two patches which in turn may each become subdivided. The wider grooves are probably those of earlier origin or are associated with large patches.

The microphotograph represents only one of a considerable number of samples that have been obtained, thus indicating that the grooving of the surface is quite a definite phenomenon. In order to measure the thickness of the surface layer as represented by the depths of the grooves, a transverse section of a specimen was polished and photographed. Fig. 11 is the photomicrograph in question, the magnification being 100 diameters. The central groove was cut very obliquely, and has accordingly a blunt "V" form.

The great majority of the groove sections examined were of practically one uniform depth. The depth of the groove and presumably of the Beta layer, is between 1/4000th and 1/5000th inch (1/200th mm.), that is, about eight wave lengths.

From the workshop point of view the specimen illustrated by Fig. 11 is remarkable on account of the very special skill involved in obtaining a clean edge that showed practically no rounding when examined with a test plate. The edge was not protected in any way, as is the common practice when preparing similar metal sections.

The Perception of Flashes of Light

The well-known and long accepted law of optics known as Bloch's Law has been proved by the researches of Mr. A. Blondel and Mr. J. Rey to be less absolute than has heretofore been believed. Bloch's Law is stated as follows: Luminous impressions produced upon the retina by sources of different intensity are equal when these sources operate during periods of time inversely proportional to the illuminations which they produce. A writer in a late number of the *Revue Scientifique* (Paris), gives a *resumé* of the work done since 1911, by Blondel and Rey with regard to the perception of brief flashes of light at the limit of their range. The object of their researches, which are of great practical, as well as theoretic interest, was to determine the minimum illumination which was capable of producing a sensation when such illumination is produced during a variable but very brief period of time. (*Journal de Phys.*, 5° série, t. I, pp. 530 and 643; 1911.—*Lumière Electrique*, 2° série, t. XXXIV, p. 54; July 15, 1916).

To return to Bloch's Law, according to this two sources are equivalent for the production of the minimum sensation when we have: (1) Et=const.; so that an illumination of 1,000 lux acting during 1/1,000 of a second would have the same effect as an illumination of 1 lux acting during one second.

Blondel and Rey have proved that this law can not be applied with any exactitude except to sources which are very intense and very brief. In the great majority of cases it is exactly contradicted by experiment. The following table gives the values, according to Blondel and Rey, of the illuminations E, which, acting during different times, produce the sensation limit of light; a third column comprises the products Et:

t	*E*	*Et*
0.001 sec.	64.1	0.0641
0.003	24.	0.0721
0.100	1.021	0.1021
0.300	0.518	0.1555
1.000	0.372	0.372
3.000	0.333	1.

It results precisely from these figures, which form a resumé of the results of 27 series of observations made by 17 observers of different ages and professions, that the product Et cannot be considered as constant.

For an increase of the duration of the illumination from 0.001 to 1 second the product Et increased from 0.0641 to 0.372, *i. e.* in the ratio of 1:6. Moreover, this increase is regular to such an extent that we can write: (2) Et=At Bt, A & B designating two experimental constants. Such is the form of the relation which Blondel and Rey propose to substitute for the law of Bloch.

To determine the constants A & B we may remark that when the illumination lasts indefinitely (t=8), the intensity perceived at the limit of the range is precisely equal to the limit of the perception, corresponding to the minimum perceptible illumination E_0; whence $B=E_0$. Moreover, if we represent by a curve the values of Et in the function of t, we prove that the representative of Et on the right cuts the axis of the abscisses at a distance representing 21/100 of a second to the left of the origin, whence $A=0.21\ E_0$, or, more generally, $A=aE_0$, designating by *a* a constant of time.

We have therefore, finally:

(3) $Et=E_0\ (0.21+t)=E_0\ (a+t)$, which may also be written: (4) $(E-E_0)t=aE_0$.

Under this last form we see that an illumination E, acting upon the retina during the time *t* may be considered as giving an evaluation of the useful excitation of the source of light.

As M. Hoorweg has remarked (*Journal de Phys.*, 5° série, t II, p. 177; 1912), the law enunciated by Blondel and Rey is of exactly the same form as the law of the limit of the excitation of muscles, according to the quantity of electricity in an electric discharge; the quantities of electricity *Q* determining the excitation vary in the function of the time *t* according to the law Q=Mt.+N, in which M and N designate the constants indicated by experience.

It seems, therefore, that we have to deal here with a particular case under a more general law, applicable to the nervous system of man, and of which the constants alone ought to differ according to the nature of the sensation. It ought to apply also to the limit of audition, but the maximum time of audition ought to be much shorter for auditory sensations than for visual sensations, since the ear separates sounds of fully less than 1/1000 of a second apart, while the eye finds it difficult to separate feeble lights less than 5/10 of a second apart.

The law of Blondel and Rey is of special interest from the practical point of view, because of the important applications of which it is susceptible in the technique of signals by flashes utilized for light-houses and projectors. Let us suppose for instance that we have at our disposal a source of light for which the quantity of illumination Et=L remains constant, the illuminations and the times being variable. According to Bloch's law the range ought to remain the same. In the law of Blondel and Rey the useful effect of the source, proportional to

$$Et-E_0t=L-E_0t,$$

increases when *t* diminishes.

To augment the range it is desirable to obtain in the shortest possible time the same quantity of illumination Et—in other words, to achieve brief signals.

This observation immediately solves the following problem of great practical interest. *Being given a source of light and the interval T between the flashes comprising its total flux, what is the duration of flash which it is most advantageous to realize by the optical apparatus in order to obtain the maximum result from the said source of light?*

Since the quantity of illumination L=Et lux-seconds at disposal for the flash is constant, and proportional to the total flux shed upon the horizon divided by the number of flashes, we perceive, by the preceding reasoning, that the effect useful at a great distance for the minimum perception will be correspondingly feebler the more we lengthen the duration of the flash. The flux should be concentrated in the briefest possible time without there being any inferior limit for this duration of concentration.

It is this very direct consequence of their law which MM. Blondel and Rey have recently verified by laboratory experiments and by experiments executed in the open air by means of industrial apparatus. In finishing this article, let us reproduce the important conclusions of this latest work of theirs:

"The results of our experiments have established indisputably that the utilization of a source of light for the production of luminous flashes succeeding each other at intervals fixed in advance, and produced by the rotation of an optical apparatus, is the better in proportion as the flashes are shorter, and that it is desirable wherever possible to cut them to 1/10 of a second if not less; the augmentation of apparent intensity thus obtained may be very considerable.

"The utilization of electrically incandescent filaments enables us to achieve extremely brief flashes. When we employ very long filaments, we can thereby augment, at equal range, divergence in the vertical direction, which it is a net advantage extremely useful for signaling apparatus, destined for aerial navigation.

"If, on the contrary, we limit the sheaves of rays exactly to the narrow vertical divergence sufficient to sweep the horizon, we can arrange a number of filaments side by side while achieving a source far more concentrated than sources in which incandescence is obtained by gasoline. Since, moreover, tungsten filaments incandescent in nitrogen achieve surface intensities which are much higher, and with an expenditure of about 0.6 watt per candle (measured perpendicularly to the axis of the filaments), we can obtain theoretically signals of much greater range, with an equal consumption of gasoline, by utilizing this gasoline in a motor driving a dynamo which causes filaments to become incandescent, than we can by vaporizing it in a lamp provided with a mentle rendered incandescent by the vapor of gasoline."

Yellow Bricks

It has been found that the yellow color of bricks is due to ferric oxide in a very finely divided form (not to compounds of the latter with lime or silica); when the ferric oxide is in a coarser condition the color of the bricks is red. Alumina appears to be the important peptising agent in bricks, which are yellow when the ratio of free alumina to iron is high; lime acts indirectly by setting free alumina. Anhydrous yellow ferric oxide has never been obtained in the pure state, but it is stabilized by other substances. The buff color of the product obtained by igniting aluminium hydroxde containing a small percentage of ferrous hydroxide is undoubtedly due to ferric oxide, as also is the yellow color of slightly impure quicklime. Clay deposited in the presence of organic matter, and therefore likely to contain very finely divided iron oxide, may burn to a buff color without the lime or alumina content being high. As agglomeration increases with the temperature, yellow bricks might be expected to turn red if heated sufficiently; but the peptizing action of alumina also increases with the temperature, and the latter appears to be the predominating factor, since red bricks become paler or even buff when reheated. The changes of color which result from the heating of yellow bricks are complicated by the dissociation of the contained ferric oxide, and heating in oxygen is suggested as a means of eliminating this factor.—*Note from the Journal of the Society of Chemical Industry* on a paper by L. A. Keane in *the Journal of Phys. Chemistry.*

The Training of the Chemical Student*

For Work in the Factory

By F. G. Donnan, F.R.S.

I HAVE already dealt with this most important subject in previous publications (*Journal of the Society of Chemical Industry; The Chemical Trade Journal and Chemical Engineer; Engineering Supplement of The Times*, July 28, 1916). To these I must refer for a fuller consideration of the subject than is perhaps possible here, and confine myself to the question of the training of the chemist in engineering science. In this connection there appear to me to be three possibilities; that is to say, three broad divisions as regards the training of a man who is going in after-life to be concerned in some fashion or in some degree with the carrying out of chemical processes on a factory scale.

1. We may give a man a thorough and extensive chemical training, but combine with it a certain amount of training in engineering principles and methods.

2. We may give a man a pretty extensive training in both chemistry and engineering.

3. We may induce men who have received or are receiving a thorough training in engineering to devote some time to a further study of chemistry, and to turn their attention to the design and working of chemical plant and apparatus.

I am well aware that it is not usually possible in actual life and practice to draw hard-and-fast distinction and to schedule in any system of precise categories the knowledge and experience of particular men. Nevertheless, in a discussion of this sort one must adopt some such system, and so for the sake of clearness of thought I propose to classify as follows:

CLASS 1. *Chemists* (Research Chemists).
CLASS 2. *Engineer-Chemists.*
CLASS 3. *Chemical Engineers.*

Hitherto our general practice in Great Britain and Ireland (with certain notable exceptions, however) has been to keep the chemist and the engineer apart, both in training and in after-life. In my opinion this practice has resulted in enormous damage to the progress and efficiency of our chemical and allied industries. We find the engineer with little or no knowledge of, or training in, chemistry in charge of the design, erection, and control of chemical plant and processes. We find him acting as process-manager and as general works manager. Nor can we blame him. Somebody has got to build the mill and make the wheels go around. We find the chemist on the other hand too often figuring as a humble "tester" (so-called "analyst") and general hanger-on to the coat-tails of the engineer-manager. This state of affairs, which all chemists must deplore, is, however, very frequently a necessary consequence of the narrow training and restricted outlook of the chemist. It is not a question merely of working in glass flasks or in metal pans. The real reason is that his training has been too narrow and specialized. He can calculate the results of an analysis. But he cannot calculate anything else. He lacks all engineering sense. He has no idea of the mechanics, the hydrostatics, the hydraulics, the thermophysics, the thermochemistry, and the thermodynamics of chemical processes. He cannot even apply the physics he has learnt. He cannot calculate heat transfer, heat efficiency. He has not been trained to think in terms of energy-efficiency at all. Nowadays he has usually learnt a little physical chemistry. But he has no idea of the vast field of application of physical chemistry in chemical industry. And as for the determination of quantitative bulk-time flow-sheets, and the calculation of the costs of power, labor, repair, depreciation, etc., he has never been given a chance to think in such terms. Yet everything I have mentioned most intimately concerns him, if he is to take his rightful place in the development and control of our chemical and allied industries.

Let me give my idea of the successful development of a new process in a well-organized industrial corporation. Let us suppose that the chemists of the research department have worked out a new process in the laboratory. They will combine in intimate coöperation with men of classes (2) and (3) in designing and testing a quite small trial plant. During this process the *special chemical engineering data* will be obtained. All three will then combine to work out the design, control, and overhead and running costs of a technical unit plant. If this appears favorable—and here the financial man has a large say in the matter—the plant is erected. In this operation the work of the engineer is very important. But it must be the chemists and the engineer-chemists who control the testing and running of the plant, who find out its imperfections, and continuously strive to remove them and so improve the economy and efficiency of the process. The working of the whole plant must be subjected to rigid scrutiny and precise calculation in every detail. The thermophysics, the thermochemistry, and the thermodynamics—to mention only three great essentials—must be fully worked out and understood. The engineer-chemists, and especially the chemical engineers, must see to it that the most economical and the most labor-saving machinery is employed, while the research chemist (or "chemist" as I have called him above), before he returns to his laboratory to work out fresh problems, must organize an accurate and detailed system of chemical and physical testing and control.

Needless to say, in actual life such sharp lines of demarcation in the division of work will not always exist. The research chemist may become an engineer-chemist or *vice versa*, or either may develop a special faculty for chemical engineering. There must be plenty of latitude allowed for the exercise and development of natural aptitudes and special abilities.

Let us now turn our attention to the training of the three classes of men dealt with above.

Men of class (1) are of course absolutely necessary. They are the discoverers of new compounds and new reactions and of the precise conditions of velocity and equilibrium. Their special field will in general be the research department. But if they are to exercise their proper vitalizing and fertilizing action in the organism, they must be highly-educated men of wide outlook and horizon. They cannot bring their special powers into fullest action if they are confined to the laboratory. They must therefore be able to coöperate intelligently with classes (2) and (3). In order to do this, one essential is that they should possess a good knowledge of *physics* and *physical chemistry*. And undoubtedly they will require some idea of engineering science. Just how much it is very difficult to say. But a course of applied mechanics and engineering drawing is certainly necessary. And I would add to that some practical thermochemistry and thermodynamics as exemplified in the drawing up of energy balance sheets for various energy-transformers, *e.g.*, boilers, furnaces, gas-producers, steam-engines, gas-engines, economizers, heat-exchanges, etc. Such studies will implant in their minds the ideas of calculation and efficiency which are so lacking in the usual chemical training. Men of class (2) are required in great numbers—indeed, in far greater numbers than men of class (1). They should receive a very considerable amount of engineering training, but it must be somewhat specialized for their proper sphere of work. Besides the matters already mentioned, they should possess a good knowledge of—

(*a*) Physical and chemical properties of materials of construction (wood, metals, alloys, refractories, glazes, enamels).

(*b*) Methods of testing materials of construction; strength of materials.

(*c*) Motion of liquids and gases; hydraulics; valves, pumps, etc.

(*d*) Thermophysics, including heat transfer.

(*e*) *Principles of design* and working of all the chief known types of chemical plant and machinery, and a good knowledge of the chief chemical technological processes.

(*f*) Generation and transmission of power; fuel economy.

(*g*) Construction of flow-sheets, calculation of costs, and design and lay-out of factories.

(*h*) The use of engineering tools.

In addition to such things, it is needless to remark that men of this class must possess certain essential qualities of *temperament*—sound "horse" sense, cool, quick judgment, power of controlling workmen, courage in the face of danger. Without these qualities of character and temperament no knowledge will be of any use. Concerning men of class (3), the essential thing is that they are thoroughly trained engineers. The more chemistry they know, the better it will be. But here again it is difficult to say how much. This much one can, however, say, and say with certainty—in chemical engineering there lies the greatest and the most lucrative field of development for engineering science. I do not think that many British engineers are alive to this fact, though it is one of vital importance.

To our standard schools and institutions of civil, mechanical, electrical heating, illuminating, and aeronautical engineers, we must add without delay schools and institutions of chemical engineering.

Other nations are already far ahead of us in this respect. There is not a moment of time to be lost. I wish now to say a few words concerning the time and method of training of the chemists and engineer-chemists. As regards the former, the culmination of their training must consist generally in the carrying out of one or two chemical researches in the chemical laboratories of the universities and higher technical schools. Their business is to be expert investigators of scientific problems. The intellectual equipment for this business is the same, whether these men remain in the universities or enter industrial research departments. A minimum of five years' training is required for this. But I would advise the directors of industrial corporations, when looking for men of high capacity, to consider the body of young university lecturers. Provided reasonably good salaries and prospects can be offered, our industrial directors who understand their business will find a rich field here awaiting encouragement and development.

The culmination of the training of the engineer-chemist must certainly also be "research." But it is research of a different, though equally important, sort. It is the investigation of the precise conditions which determine how a given chemical process can best be carried out on a technical scale. There is no better way of doing this than by directing the attention of the student to some substance, reaction, or patented process which appears to possess, or which may, if developed, possess, commercial interest and importance. The research then consists in the investigation of the precise quantitative optimum conditions of the reaction, the determination of the various physical and engineering data required for the design of plant to carry it out, and the actual construction and running of a small experimental plant wherein the process is realized. It is just here that the greatest lacuna in our present educational institution exists. We want and *must have* cheap, rough buildings—sheds, if you like—well supplied with water, power, steam, gas, draught, and drainage, where such things can be done. They must be supplied with foundries, forges, and engineering shops where the necessary gear can be made with reasonable facility. And, indeed, the young engineer-chemist will learn a good many lessons of practical life in these shops. It is also my hope that many young well-trained engineers, the "chemical engineers" of the future, will make use of such "laboratories" also, and will, as part of their training, coöperate with the young engineer-chemists in the economical and scientific realization of chemical processes. I do not think that such "operation laboratories" need be terribly expensive, as some people fear. The real essential is that the work should be everywhere accurate and *quantitative* as regards materials, energy, and cost. I regard the work of the engineer-chemist as essentially *applied physical chemistry*. If we interpret that expression correctly and with sufficient width of view, I think we shall find therein the key to the whole situation. The engineer-chemist is a chemist, not an engineer. But he must be a chemist with a wide knowledge of physical chemistry and imbued with the *spirit* and method of the best type of engineer.

I estimate the minimum time for his period of training at five years. During this period of time he will gain much if he can work during some of his long vacations in chemical or allied factories. I make a solemn appeal to our manufacturers to arrange this. I appeal to them also to provide money for the carrying out of the things I have indicated above. We can do nothing if they will not help us. We *must* speed up our intellectual potential. There is not an hour to be lost. Otherwise the declaration of peace will be but the reopening of our previous condition of senile decay—a pleasant reward, indeed, for the hosts of young men who have risked their health and life on our behalf. Let us not ask for State protection until we can *prove* that we deserve it and are fit to derive national benefit therefrom. To him that hath shall be given.

* A Contribution to a General Discussion on "The Training and Work of the Chemical Engineer," held by the Faraday Society, March 6, 1917. Report from the *Chemical News*.

A Quality of Electrolytic Iron

IF a sheet of electrolytic iron and one of ordinary rolled iron are cleaned of scale and oxide; and set up as a battery with dilute sulphuric acid, a millvoltmeter will show that the electrolytic iron is electro-positive to the common iron. It will be appreciated from this that a coating of electrolytic iron is under many circumstances a desirable protective coating.

Gathering Turpentine

Suggestions for Prolonging the Naval Stores Industry

By Samuel J. Record, Assistant Professor of Forest Products, Yale University

The future of the naval stores industry in the United States is a matter of grave concern. Wasteful methods of boxing and chipping are carried on in advance of logging operations and no provision is made for continual production. Long leaf and Cuban pines of the South have long been the chief source of the world's resin supply, but the stands of these trees are rapidly being cut. The demand for naval stores, however, is increasing, and this has led to the boxing of smaller trees and of species which formerly were not considered worth while. With depletion of the forests the industry has advanced farther and farther west until practically the whole range of long leaf pine has been covered. There is no other region to exploit unless it be the far West. Investigations of the yield of resin from western pines indicate a possible future for the naval stores industry, but it can never approach conditions in the South Atlantic States.

Decrease in supply has also stimulated the distillation of pine wood, and while there is considerable prejudice against the turpentine thus obtained it nevertheless has a promising future. Improved methods of distillation are coming into use which overcome most of the objections to wood spirit.

For ten years the United States Forest Service has been experimenting with improved methods of turpentine orcharding. Instead of the destructive box cut into the base of the tree, thereby weakening it and rendering it particularly liable to fire damage, a system of cups and gutters was shown to be successful. The adoption of this method has been slow and even at the present time the old way is still common.

The next important feature of turpentining presenting itself for investigation was in regard to the proper depth, width and height of the wound made on a tree in chipping. Some of the results of the comparative experiments conducted on a commercial scale under normal conditions demonstrate that combined shallow and narrow chipping increases the yield; that the number of trees killed is decreased; and that the damage to the lumber in the butt cut of chipped trees is reduced.

Light cupping, that is, restricting the operation to timber over twelve inches in diameter, and closely limiting the number of cups per tree, has proved to be highly advantageous, since it prolongs the period during which a crop can be worked and by exempting the young trees prevents the exhaustion of the timber available for turpentine in future, thus assuring stability and perpetuity to the naval stores industry.

Resin will not continue to flow indefinitely from a cut, hence frequent chipping (once a week or oftener) throughout the season is necessary to maintain the flow. Cuban pine bleeds much longer than any others, producing almost no "scrape." The thickness or rather the height of the chip taken off determines the rate of advance of the face up the tree. The more cut off at a time the sooner the face will get beyond the reach of the chipper. It has been demonstrated that a thin shaving will accomplish as good or even better results than a heavy cut. With the ordinary hack, however, this is difficult to regulate, and a new hack has been invented which works on the principle of a safety razor. The thickness of chip can be gaged accurately even after repeated sharpening of the hack blade. It is so made that the inside edge is flat instead of curved, thus leaving the cut face smooth instead of scalloped. This facilitates the flow of resin into the cups.

The question of running the face spirally instead of straight up the side of the tree is being considered. The advantage of the spiral would be in extending the length of time a tree could be chipped before the face got beyond reach of the long-handled hack. It might at first appear that the effect of a spiral face would be to girdle the tree as soon as it had extended entirely around. Such is not the case, however, since the movement of the sap is not in straight lines, but from one cell to another through pits in the side walls. The sap stream would accordingly follow the spiral of uninjured wood without material interruption.

A method of resin gathering for which a great deal has been claimed consists of boring slanting holes in the sapwood and draining the resin into a closed cup. This was supposed to prevent the closing of the resin ducts by oxidation of the resin, thus permitting a continuous flow. This and similar methods fail to take into account the physiological processes involved in resin formation.

Resin is a waste product resulting from the vital processes of growth. It is not, as many assert, a healing balsam especially produced by the tree to protect wounds; such a function of it being purely incidental. In the change of starch into exactly the kind of food the plant wants a complex substance is left over as a by-product. This is called resin and is found in parenchyma cells since they alternately store up and give out starch and other plant food, according to the season.

If several resin cells or parenchyma cells are close together the amount of by-product (resin) becomes too

Method of removing the outer bark in preparation for setting the apron and cup for a flow

large to be contained in the cells and is excreted into intercellular spaces Such spaces are known as resin ducts and are characteristic of the wood of our pines, spruces, larches and Douglas fir. Most of them extend up and down the stem, but many occur in the large medullary rays. These ducts are for use in the storage of resin and not for its transfer from one part of a tree to another. In this function as well as the absence of a wall of their own they differ from the vessels of hardwoods. None of our hardwoods contain resin ducts in the wood, though many species of *Dipterocarpaceæ* in the Philippines are so characterized. The milk of dandelion, of milkweed, and the latex of rubber trees is also a by-product similar to resin in formation.

In tapping a tree comparatively little resin is actually secured from the ducts already in the wood. The main flow is not out of the old ducts like sap out of cut vessels, but is from new ducts which arise as a consequence of the injury. Wounding, such as chipping, stimulates the vital processes at the seat of injury and greatly increases the by-product, resin; and in consequence there is an increase in the number of ducts necessary to contain it. It is from these secondary ducts that most of the commercial yield of turpentine is secured.

The first wound results in the formation of a number of new or secondary resin ducts from both above the below the injury, the length of those above being greater than those below. Subsequent chipping of course affects only the upper edge of the first wound. The first wound is usually made in winter when all hands are engaged either in placing the cups on the trees or in cutting the boxes preparatory for the next season's flow. As a result of this work a certain amount of crude turpentine is collected during the winter, but it is almost entirely from ducts already in the wood and not from secondary ones. The flow of this resin does not continue very long, for the wound becomes clogged, presumably from oxidation and crystallization of the resin, and the flow ceases.

The secondary resin ducts formed above the wound are filled with resin which has no opportunity to escape until a thin chip is cut off. When this is done the flow is much more vigorous than from the original wound. In about a week, however, clogging up occurs again and another chip must be removed. As this wound extends slowly up the tree new or secondary ducts keep pace with it. If too large a chip is cut the productive secondary ducts are cut off and the run materially lessened.

Failure to understand the physiology of resin formation and to adjust the methods of turpentine orcharding to it has resulted in untold losses and a very serious depletion of a valuable resource. It is also responsible for one of the chief criticisms against the cup and gutter system. It is a common experience that, although the total yield from the first year of the operation is greater than under the box system, nevertheless an unusually large number of weekly chippings has been found necessary to secure the first dipping from cups—six to seven chippings as compared to four under the box system.

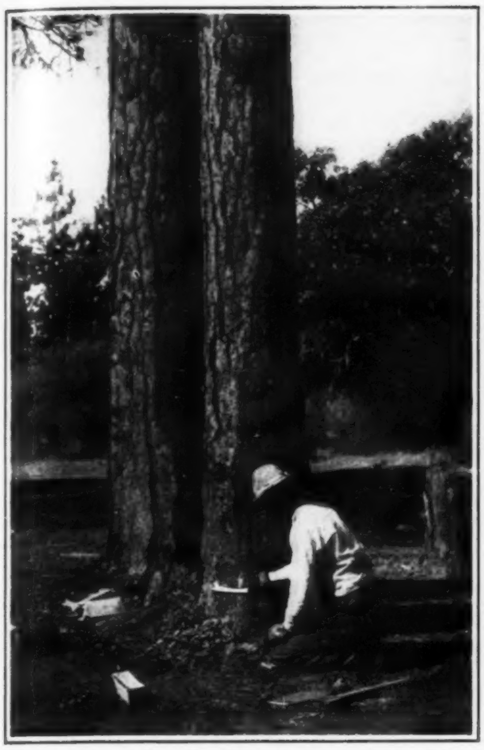
In the light of the above explanation of the formation of secondary resin ducts this shortcoming is readily explained and avoided. Under the box system the boxes are cut during the winter and the trees are "cornered," that is with the upper edge of the face ready for chipping. The new ducts form, the first chip opens them up the full length of the cut and a good run is at once secured. In placing cups, however, the common practice has been to make with the broad ax two flat faces, meeting at the center, on which the cuts for insertion of the gutters are made. The upper portions of these faces have oval outlines instead of straight as in the preceding case. The resin ducts formed follow the curved upper edges of the faces. The first chipping is made from each side to the center, and the result is that instead of the new ducts being opened up along the entire cut, only those near the middle of the face are cut. Naturally the flow at first is considerably less than where the trees are "cornered."

The solution of the difficulty presents itself immediately the cause is understood. During the winter months, when the gutters are placed upon the trees, the chipper should make a regular chipping the full width of the face. Secondary resin ducts will form along the entire length of this cut and the first application of the hack in the spring will start them all to flowing at once. Actual tests have demonstrated the correctness of the theory and resulted in a gain of one extra dipping or about thirty barrels of crude turpentine per crop of 10,000 cups. The saving to the entire industry is enormous.

French turpentine is considered superior to American. It is obtained from maritime pine (*Pinus maritima*), which produces a resin yielding 25 per cent turpentine as compared to 17 per cent for long leaf pine. The tree has the ability to grow rapidly on poor sandy soils. The United States Forest Service is now experimenting with it in Florida, and the prospects are so far very promising. Maritime pine grows more rapidly than loblolly and produces more resin than long leaf. It attains size large enough to cup in thirty years as compared to one hundred years for long leaf. There are large areas of cheap land in the South which are well adapted to its growth in case the experimental plantations fulfill their present promise.

Animals That Make Trouble for Themselves

A well-known trait of captive giraffes is to get into all kinds of unecessary trouble unless ceaseless vigilance of the keeper eliminates all possibility of mishaps. Sometimes giraffes develop traits that point to future trouble, and that must therefore be forestalled. Owing to the habit of our present specimen in the Bronx Zoölogical Park of standing with his fore feet in the porcelain drinking trough, two feet from the floor, we built a protecting wooden ledge to prevent him from slipping out of the smooth basin. He then developed a disposition to thrust his elongated forelimbs so far through the front bars of his cage that it was necessary to cover the lower part of the cage with wire netting. Persistently bumping his nose against a door ledge was counteracted by a rounded moulding. When he started to rub the hair from his neck on an iron brace about twelve feet from the floor, this was duly prevented, and then the animal started to gnaw the door frame. With the wood protected with sheet metal, the giraffe concentrated his attention upon the plaster top of a column, from which he playfully bit generous fragments. We covered the top of the column with wire mesh, and next morning were horrified to find that he had so demoralized the mesh with his teeth that numerous wires stuck out in all directions like porcupine quills, and precisely on a level with his eyes. Fortunately his eyes were not injured; and then the column top was covered with heavy sheet-metal. We anticipate further and varied developments, at any time.—*N. Y. Zoological Society Bulletin.*



Showing the method of setting the apron in orchard turpentining, after the removal of the bark from the tree

Streaking or chipping. Starting the face. Note the nail below the apron upon which the cup is hung

A fairly typical face. The hack, which shaves on the principle of a safety razor, lies beside the tree

Some Applications of Fluorescence and Phosphorescence*

By J. S. Dow

The subject for discussion is one on which little is generally known. These phenomena, and their relation to the complex problems underlying the production of light, are of great interest to the Society. The use of luminescence in such illuminants as the flame arc, the mercury vapor lamp, and possibly the incandescent mantle, are of interest, as suggesting the possibility of more efficient light-production than can be obtained by incandescent effects; and also because they involve free vibrations of certain wave lengths, offering the hope that eventually we may be able to control the color of light for various purposes, as easily as we now control the intensity. The firefly has long been regarded as one of the most efficient sources of light, and researches on phosphorescent substances suggest that such forms of "cold light," though relatively feeble in intensity, have almost invariably a very high luminous efficiency. Yet the experiments on this point are a little doubtful in view of the very low luminosity, and the possibly misleading effect of the physiological complexities of the eye in such circumstances. From a scientific standpoint it would be very desirable to determine the luminous efficiency of such processes with greater precision.

The effect of such substances in the dark is also of interest in view of its bearing on the matter discussed at the last meeting—the influence of glare and contrast. The visibility of these substances depends very much on the state of adaptation of the eye. A small patch of luminous paint, particularly the blue light from phosphorescent calcium sulfide, can only be seen with difficulty by an eye recently adapted to ordinary artificial light. On the other hand, in the writer's experience, the brighter forms of self-luminous paint may, to a fully dark-adapted eye, produce an effect not unlike actual glare. It is therefore very important to determine the minimum brightness requisite for various purposes, and not to exceed this minimum. Another effect, also clearly in evidence with the blue light of calcium sulfide is the "spreading" of the light at distances exceeding a few feet, owing presumably to the chromatic aberration of the eye. Again, a patch subtending a small angle of the eye appears much less bright than a relatively large area, which also tends to make the surface painted fade out of sight, and, indeed, become invisible to direct vision, at a short distance away. These effects limit the applications of such substances in their more feebly luminescent forms. Except when one can deal with relatively large areas, they are best suited to near vision. For the same reasons the photometry of a small area may not give the true effect of their use over a large surface.

As regards the order of brightness met with, it would appear from tests by various observers on various self-luminous paints (zinc sulfide) that the following rough rule might be tentatively suggested, namely, that the actual brightness in equivalent foot candles is rather less than one-tenth of the radium content in one gramme of composition. Thus 0.4 composition (*i. e.*, material containing 0.4 milligrams to one gramme of radium bromide and zinc sulphide), yields *about* 0.04 foot-candles, and 0.2 composition *about* 0.02 foot-candles (*i. e.*, about the brightness of a white surface illuminated by full moonlight). For reasons already given, it is impossible to state such a rule with precision, but as a rough guide this may be useful. To much more powerful compositions it may not apply.

The brightness of zinc sulfide or calcium sulfide a few minutes after exposure at close range to a 50-watt electric incandescent lamp (which is typical of the type of source available to the ordinary householder) is already very much less than the "moonlight" value. From tests on some samples of the calcium sulfide "luminous buttons" now being sold for use in the dark streets, the writer has found that, after the above exposure,they were practically indistinguishable to direct vision at a distance of ten feet, within an hour after exposure. These buttons were about 1½ inch in diameter. The brightness in such circumstances would, therefore, not be of much help in enabling people to avoid being run over by vehicles; but they might be useful in preventing collisions of pedestrians in very dark areas. On the other hand, if such material was available in large quantities for coating kerbs, lamp posts, etc., the larger area treated would alter the problem, and they might possibly have applications in places where there is practically no artificial light provided, or in enabling a party to keep in touch with one another when traversing a wood at night. The successful use of such devices seems at present to demand conditions of such low luminosity as practically excludes the use of artificial light. Otherwise a piece of white card may appear equally bright. On the other hand, little is known regarding the persistence of luminosity excited by sources very rich in ultra-violet light, such as the quartz tube mercury vapor lamp. After such exposure effects sufficiently permanent to be used for theatrical effects are said to have been produced. Luminous paint is also said to have been used for coating buoys and other marine objects, the luminosity induced by the sun's rays being reproduced during the dark hours of the night. In the absence of any artificial light this project seems more feasible, especially in the strong sunlight of the tropics. Luminescing materials have been found useful for many special purposes since the outbreak of war. If phosphorescing substances could be produced commercially on a large scale and at a cheap rate, new applications would doubtless present themselves (for example in underground passages and mines, for luminous danger-signs and other notices, etc., and for advertisements and specular purposes). In small quantities their successful use seems to demand frequent excitation by sources rich in ultra-violet rays. The writer has tried coating switches with calcium sulfide, but the relatively low general illumination in an ordinary interior is not as a rule enough to produce a useful effect.

On the other hand, the self-luminous materials, continuously excited by radium, have already many important special applications. The chief present limitations to their wider use are scarcity of supply and expense. It has, however, been recently calculated by a writer in the *Electrical World* that the weaker and less expensive forms of such materials could be used for coating switches at a cost of only 1d.-1½d. per switch.

*An introduction to a discussion before the Illuminating Engineering Society, England, and published in *The Illuminating Engineer*.

A Convenient Method of Fixing Carpets and Hangings

The press button system with which we are familiar in gloves and garments has been applied by an European inventor for fixing carpets, tapestry hangings and the like. For instance, a small spring socket is inserted flush with the floor, and the carpet carries a corresponding projection, so that all that is needed to lay a carpet or rug is to push the bottons into the sockets. Again, the projections are mounted along a stout tape band and the sockets on another, quite like the usual pressure button. One tape is sewed to the rug and another can be tacked down upon an already laid carpet, so that the rug can be laid or removed instantly. Hangings can be put on the walls in the same way. Or in another case, the wall is covered with cloth fabric put on by the use of the present system, then the tapestry hanging or panel can be mounted on top of this again, the whole being carried out by the use of the prepared tape. Curtains or portiéres can also be mounted; and all such material can be at once removed for cleaning. In case of fire, valuable hangings can be saved.

Securing Window Glass

Glass panes can be held in place without the use of putty by the use of a flexible metal or rubber strip like a partly-open tube laid upon the pane and held down by a set of clamps spaced along the pane. First apply the pane of glass so as to fit it into the usual recess, then lay the prepared metal or spring strip along one side and screw on a plate at the corners of the pane and say one at the middle, these being flat plates with a somewhat incurved edge where they take hold of the spring strip, and are screwed on to the woodwork at the side of the pane with the curved ends projecting out and over the pane so as to enclose the strip. The latter are of course put on at all four sides of the pane. A double pane with air space between can be applied by using a deep recess and just laying a pane, then the strip, next a second pane and finally a strip that now comes flush with the woodwork and can be fastened down by the metal plate as before.

Timber Decay*

And Its Growing Importance to the Engineer and Architect

By C. J. Humphry[1]

To the structural engineer and architect timber decay is becoming of ever increasing importance, due largely to the fact that the timbers which have entered into the construction of many important buildings during the past decade or two have failed to give the service expected of them.

It is a matter of common knowledge that this unsatisfactory record of service is primarily the result of using timber inferior in its resistance to decay; however, there also enter into the question in certain instances very obvious errors in design and construction. In the earlier days, when a large percentage of high grade structural timbers was available, delinquencies in construction did not result so disastrously and, hence, attracted much less attention from members of the engineering profession.

At the present time the greater part of the structural timber in use east of the Mississippi River consists of southern pine comprising five species, the more important of which are the longleaf, shortleaf and loblolly. The longleaf pine undoubtedly contains a larger percentage of the more durable grades than either of the other two species. Unfortunately in the trade, a confusion of the species has occurred which has resulted in the flooding of the markets, the northern ones in particular, with inferior timber cut from loblolly and shortleaf. The general demand for low-priced timber on the part of the builder has thrown the true longleaf largely out of competition, there having been, until recently, a heavy export trade in this species.

To further aggravate the situation, structural sizes of both loblolly and shortleaf have, in many cases, been cut from small rapid growth trees or knotty tops with a high percentage of sapwood, the clearer, more valuable logs being cut into 1 or 2-inch lumber.

We are now reaping the harvest from the use of this low grade stock. It is only within the past two years that better timber has become available to those who desire it and are willing to pay the price for select stock. This improvement is largely the result of the adoption by different societies and lumbermen's associations of the Forest Service density rule, which gives adequate specifications for quality grades of southern pine.

WHAT CAUSES DECAY?

Before entering the discussion further it may be well to outline to you briefly the causes of decay and the environmental factors which promote it. Decay is due almost entirely to the growth of wood-destroying fungi within the tissues of the wood.

There are many hundreds of different fungi which disintegrate wood in the forest, but the greater part of the economic losses in structural timber is referable to a comparatively few species.

These fungi are plants just as much as are trees and herbs. They differ merely in their form, lack of green coloring matter and methods of nutrition. While green plants absorb their food supplies from the soil through their roots, fungi derive their nutriment from the substance of the wood.

In the life-cycle of a wood-destroying fungus there are two distinct stages: (1) The vegetative stage, consisting of thread-like, usually much branched, filaments, termed *mycelium;* (2) the fruiting stage, which is nothing more than a compact mass of mycelium which takes on a definite form on the surface of the decaying timbers and serves for the production of spores and, hence, the propagation of the species.

MYCELIUM

Usually this is confined within the wood substance, the fine cotton-like filaments ramifying throughout the tissues and filling the pores of the wood and the cells of the pith rays, as well as boring through the walls of the wood elements. It can roughly be compared to the root system of ordinary plants for its function is the same, namely, that of an absorbing system.

In order to render the constituents of the wood available for food they must first be reduced to simpler organic compounds which can be absorbed readily through the walls of the mycelial filaments. This is accomplished by the secretion of organized ferments which have the capacity of acting chemically upon the wood and splitting up the complex compounds into their simpler components.

Sapwood is, in most cases, more susceptible to decay than heartwood because it contains a greater amount of the more easily digested compounds, and, unlike the heartwood in many kinds of timber, is not infiltrated with compounds which in themselves retard the growth of the organisms.

CONDITIONS ESSENTIAL TO MYCELIAL GROWTH

In addition to available food supplies, fungi require certain essential conditions for their development. These are: 1, sufficient moisture; 2, at least a small amount of air within the wood; and 3, a suitable temperature.

Moisture.—A suitable amount of moisture is, without doubt, the most important factor in decay. The different wood-destroying fungi appear to have their own particular minimum necessary to fulfill growth requirements. Certain ones classified as "dry rot" organisms seem to get along on a comparatively small amount, while others thrive only in highly humid surroundings. In the case of "dry rot" fungi it appears to be more a question of the ability of the organisms to tolerate dry conditions, or to produce their own moisture from the wood than any essential need for such conditions, for observations and laboratory tests demonstrate that an increase in the moisture under such circumstances leads to more rapid decay.

The need for at least a certain minimum of water is well shown under practical conditions. The points of failure in ordinary dry buildings are the points at which a little extra water is brought to, or held within, the timbers; for example, the ends of joists or girders set in brick or concrete walls, outer window casings, wood surrounding water pipes which may sweat or occasionally burst, porch floors and ceilings and other exposed trimmings where atmospheric moisture may collect at the joints, and last and often most important, basement timbers, either in contact with or close to moist soil.

Most people are familiar with the way in which posts and telephone poles rot at or near the ground line. Below the ground line the sapwood completely decays, while above the ground line a thin shell of dry hard outer wood remains, with the decay running up beneath it. This is entirely a result of moisture conditions. The same phenomenon often occurs in water tank staves where the outer face is too dry and the inner face too wet to decay, while an intermediate zone may completely disintegrate.

This, then, leads us to the discussion of another factor in decay, namely, air.

Air.—A certain amount of air within the wood is absolutely necessary for decay. The organisms need it for their growth. In saturated wood, the air is, for the most part, displaced by water and fungus growth is impossible.

ALTERNATE WET AND DRY CONDITIONS

The very wide-spread idea that decay is due to alternate wet and dry conditions has developed through observation of the way timbers behave when exposed to the elements. Take, for instance, a railway tie partly embedded in soil. During a dry season it may dry out to such an extent that decay is very slow, then come the rains, and if only sufficient water falls to put the tie in a good moisture condition it begins to rot rapidly again, and will continue to do so as long as the moisture and temperature are favorable. If, on the other hand, there is a long-continued rainy period, the tie may soon become saturated and decay will stop again and remain practically at a standstill until the stick dries out sufficiently to admit the *necessary* amount of air. Thus, in the alternation of wet and dry conditions, one gets at some point intermediate between the dry and wet ranges a condition at which decay is at its maximum. If the timber were *maintained at this optimum point,* decay of the stick would be at its greatest and the alternating wet and dry conditions *would be unfavorable.* It is only under fluctuating natural conditions that alternation becomes of advantage.

Temperature.—The third essential condition for rapid fungous growth is a suitable temperature. For the majority of species the most favorable temperature lies between 75 and 85 degrees Fahr. (24-30 degrees C.) There are some exceptions to this, however, in the case of certain of our very destructive fungi. Of a series of some 50 species which we have tested in our laboratory, none would grow above 118 degrees Fahr. However, this does not necessarily mean that they would be quickly killed at this temperature.

In general, wood-destroying fungi are much less tolerant of high temperatures than low ones, the high temperature inhibition point rarely exceeding 20 degrees C. above the optimum, while temperatures slightly above the freezing point will usually permit some growth. In fact, the writer stores a large number of stock cultures of different fungi in an ice box where the temperatures vary around 10-15 degrees C. Under these conditions, several fungi isolated from building timbers grow luxuriantly.

The fact that all the species of fungi occurring naturally in a given locality can withstand the most severe winter weather shows their extreme hardiness to low temperatures. While growth may be almost completely suspended under these circumstances, the organisms will normally recover their growth capacity soon after being placed under more favorable conditions.

In the case of the true dry-rot fungus, *Merulius lachrymans,* its reaction to high temperatures is used as the basis for control measures.

Light.—As a rule, light exerts a retarding effect on mycelial growth. This may amount to as much as an 18 per cent reduction.

VITALITY OF MYCELIUM

Mycelium in wood is often very long-lived in timber dried in the air at moderate temperatures. Once it gets well distributed throughout the wood, it is doubtful, in very many cases, whether the wood can again become free of infection as a result of natural atmospheric conditions. One case on record shows that a stick infected with one of our common species contained very vigorous mycelium after having been kept in a warm dry room for four years.

FRUITING-BODIES

The second stage in the life-cycle of a wood-destroying fungus consists in brackets or shelves, "toadstools," or often only compact incrustations which appear on the surface of the timber after decay has become well started. Their function is to produce spores, which are comparable to the seeds of ordinary green plants. Being very minute (finer than flour) these spores are readily carried about by air currents and lodging on the surface of moist timber, at a favorable temperature, germinate to produce new infections. The number of spores produced is beyond the ordinary comprehension. According to Professor Buller's studies on *Polyporus squamosus,* the number of spores produced by a single specimen of this fungus may in the course of a year be "some fifty times the population of the globe."

A large part of the infection of timbers in the open occurs through the agency of these spores, but in buildings, where fruit-bodies are less likely to develop, they play a less important rôle.

DECAY IN BUILDING TIMBERS

Having now briefly reviewed the conditions which favor the development of rot-producing fungi, I will cite a few specific instances of the more serious fungus outbreaks which have come to my personal attention. All of these cases could readily have been prevented had the men in charge of the design and construction been familiar with the fundamental conditions which invariably lead to rapid decay.

The principal sources of danger fall, roughly, under the six following heads:

(1) Placing non-durable timber in moist, ill-ventilated basements or enclosures beneath the first floor, or laying sills in direct contact with the ground.

(2) Embedding the girders and joists in brick or concrete without boxing the ends.

(3) Placing laminated flooring in unheated buildings in a green or wet condition.

(4) Covering girders, posts or laminated flooring with plaster or similar coating before thoroughly dried.

(5) General use of non-durable grades of timber in a green or only partially seasoned condition.

(6) Use of even dry timber of low natural durability in buildings artificially humidified to a high degree, as in textile mills.

A further element of danger lies in the use of timber infected during storage or which has become infected through neglect after purchase and delivery.

Poor Ventilation in Basements.—A considerable number of cases where poor ventilation beneath buildings, principally warehouses and frame structures, has started serious infections have come to the writer's notice. One case will suffice for illustration. This was a wholesale carpet and rug warehouse in a city on the Pacific coast. It was a one-story frame building four and one-half years old, with solid concrete foundations, except for four small screened ventilators in front about 5 inches by 18 inches in size. The building was set about 2

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[1]Pathologist, Forest Products Laboratory, U. S. Department of Agriculture, Madison, Wis.

feet above the ground and the air beneath the floor was stagnant and very humid, especially at the back end, where the infection started. In the course of about three years the fungus (probably the dry-rot fungus, *Meruluis lachrymans*) had rotted out a portion of the floor girders, joists and flooring, and had done some injury to stored rugs. At this time repairs were made beneath the floor and also a new floor was laid on top of the old one. In less than a year the new floor and also the bottom of racks resting on it were badly rotted, causing further injury to the carpet and rug stock. In one case the fungus passed through the floor, the base of a rack about one inch off the floor, and twelve thicknesses of heavy rugs, eating large holes in them.

Embedding Timbers in Brick or Concrete.—Cases where girders and joists embedded in brick or concrete walls have rotted off in a short period of time are not uncommon. The writer has investigated one case on the Pacific coast with considerable care. This was an unheated mill-constructed building used as a hardware warehouse. Heavy 12 by 20 Douglas fir girders, in a green condition, had been covered tightly with light galvanized iron at the ends and then embedded for about 18 inches, without boxing, in concrete pillars at the outer walls. In about four and one-half years many of the timbers were thoroughly rotted at the ends and had to be removed. In an effort to control the rot, the concrete has been chipped away from the ends of the girders to allow them to dry. Borings taken in May, 1916 (after chipping away the concrete), in two girders between the depths of 4 and 6 inches, show the following moisture percentages:

1 foot from end—19-20 per cent. 2 feet from end—14-16 per cent. 5 feet from end—11-13 per cent.

It is thus seen that the timbers were then in an air-dry condition at 5 feet from the ends. Very little, if any, rot has developed at these points.

Laboratory studies have shown that small samples of the rotten girders sent to Madison in October, 1915, and stored in a dry place until March, 1916, still retained the fungus in a vigorous condition. The optimum temperature for growth has been found to be 25 degrees C. The wood, however, will withstand a temperature of 43.5 degrees C. (110 degrees Fahr.) for 48 hours without markedly impairing the vitality of the mycelium.

Laminated Flooring.—There seems to be some divergence of opinion regarding the use of laminated floorings. In many buildings it has proven completely satisfactory. In others it has given very poor service. All the complaints investigated by the writer have shown the trouble to be due to the use of wet material. This, at best, dries very slowly in an unheated building. Covering such timber with plaster, or any other heavy coating, when moist will almost invariably cause trouble. If difficulties with laminated flooring are to be avoided, the timbers will have to be thoroughly air seasoned and kept dry during construction.

Covering Timbers.—This leads us to a consideration of the advisability of covering materials in mill-constructed buildings. A number of cases already investigated indicate clearly that the practice should not be recommended except with extreme caution, and a close knowledge of the condition of the timber as it goes into the building. I will cite but one case. This occurred in a mill-constructed building in Chicago which I have been permitted to examine through the courtesy of one of your prominent engineers. This building was erected about three years ago, the construction being under way throughout the winter, so that the timbers were subject to periodic wetting from rains and snow. Such timbers as I have seen removed from the building on account of decay were, for the most part, of poor quality, low density, mostly rapid growth, very knotty and often with a large proportion of sapwood. Of eight girders and posts which were identified for species, seven proved to be loblolly pine and one shortleaf.

Laminated floors of mixed quality, usually sappy and wide ringed southern pine, scant 3 by 6, were laid throughout the building, with the ends resting directly on the girders, with about a 6-inch bearing. The ceiling, girders and posts were all encased in plaster board, leaving a narrow air space between the board and timbers.

This combination of circumstances—low quality timber, high moisture content, and plaster board covering—caused the timber to rot rapidly, particularly at the bearings of the laminated floor on the girders.

At the time the writer inspected the building the timbers had reached an air-dry condition for a heated building and the fungus was apparently dead except on the top (seventh) floor. During the time in which the timbers were drying to this point, however, the fungus had ample opportunity to produce serious decay in many of the timbers which resulted in the removal of a considerable number.

Use of Non-Durable Timber in Textile Mills.—In textile mills where high artificial humidities are constantly maintained, the decay problem is very much aggravated.[2]

HOW TO CONTROL DECAY

This phase of the subject can best be discussed under two main heads: 1, Prevention; 2, Eradiction.

Prevention of Infections.—The possibility that timber may reach the consumer with infection already in it is by no means remote. Many lumber yards are in a highly unsanitary condition as regards the presence of destructive fungi. For this reason the material should be carefully inspected and all pieces bearing incipient rot rejected. Likewise, it may prove advisable to inspect the yard where the purchase is made.

Upon delivery of the material it should not be thrown about on the ground, but should carefully be placed on skids and kept dry. The soil is often a prolific source of infection.

Such timbers as are to be placed in situations favorable to decay should either be select grades of naturally durable stock or else treated with a good wood preservative. Neither non-durable timber nor sapwood is objectionable when used in a *dry* condition and *kept dry*. Hence, every effort should be made during construction to keep moisture away from the timbers, and especially the joints.

Moist timbers should never be cased in, nor should timber of any sort be embedded in concrete or brick walls without boxing.

In all cases thorough ventilation of moist, stagnant basements should be provided.

Eradication of Infections.—Whenever timbers begin to fail, the need of a thorough inspection of the building is indicated. If poor ventilation is the cause, the building should be opened up to secure rapid drying of the timbers. At the same time tests should be made to determine whether the wood contains living fungus. It is also important to know what species the fungus is, as further control measures may hinge on its identity. For instance, the true dry-rot fungus, *Merulius lachrymans*, being a low temperature organism, can be controlled by the application of heat, while such a procedure would be useless with most other species. Some fungi may also prove susceptible to a certain amount of drying, where others would not.

Where serious and active decay exists, without the exact method of control being indicated, the timbers should be carefully removed and replaced with select durable stock or with lower grade material treated with antiseptics. Likewise all incipient infection which appears in timbers which it is not considered necessary to remove should be given two or three applications of a wood preservative. Either a hot 3 to 4 per cent water solution of sodium fluoride or a cold 1 per cent alcoholic solution of mercuric chloride is well suited to interior timbers. Exterior timbers, where odor and color are not objectionable, can be satisfactorily treated with a good grade of hot coal tar creosote.

The Molds That Injure Paper

By Pierre Sée*

PAPER, as is well known, undergoes certain alterations in the course of time. These are produced particularly by humidity and consist in the appearance of pigmented specks such as are observed in the spotted pages of old books. The damage is due, as has been demonstrated by experiments made by me, to the presence of certain inferior fungi. Some of these secrete a pigment which is diffused in the fibers of the paper, and whose tint varies according to the species. Careful examination of a spot thus produced enables us to perceive that it is composed of two portions: a central part, generally rather deep in tone, and constituted by the mycelium, and a nearly circular peripheral zone, which is lighter in tint, colored by the secretions of the fungus, and often visible on both sides of the sheet of paper by reason of the diffusion of the pigment.

Molds may vegetate thus under very various circumstances. Some of them, like the *Alternaria*, are reduced to a form of preservation which is encysted, fragmentic and fragmentary, recalling the fumagoid state. Other species, *e.g.*, the *Strachybotrys* yield spores, which are perceived in the form of a black powder, on separating from the fibers of the paper. Sometimes, and this is the case with the *Chætomium*, we may observe the presence of a perfectly developed fungus.

The germs of these true maladies of paper are not caused by any sort of late infection, but pre-exist in the pulp from which the paper is made, and probably proceed from the materials used in making paper pulp, such as straw, alfalfa fiber, etc.

If, in fact, we observe closely paper recently manufactured, either by direct or by transmitted light, we perceive spots which are variable in color, size, and extent, and which even at times stand out in a relief which is perceptible to the sense of touch. Some of these are constituted by living mycelian elements which are quite capable of development in favorable conditions.

I have systematically cultivated myceliums collected either from papers which have become spontaneously spotted or from samples of pulps or papers taken as aseptically as possible. These were then placed in tubes, or sterlized cupels to grow moldy. I have chosen for this purpose samples of papers very different both in origin and in manufacture (papers sized and unsized, filter paper, printing paper, etc.).

I have utilized various mediums and various processes in making these cultures (carrot, potato, gelatin, bread, wood, paper, Borrel tubes, van Tieghem cells, etc.).

I have thus been enabled easily to recognize that the mycelium belongs at times to various molds, not all of which necessarily are pigmented, but that often also, it is pure, and furnishes a single species. I have also observed that in spite of the diversity of the primitive substance and of the experimental conditions, the fungi isolated are always the same, and that their number is limited. Hence they constitute a flora peculiar to the highly specialized medium formed by paper.

Certain fungi, such as the *Chætomium* or the *Acrostalagmus* produce a spot so characteristic that simple examination suffices to reveal their presence. I have been able to reproduce experimentally all these spots peculiar to paper by sowing the various fungi on bands of sterilized paper, and without the addition of any nutritive substance. The species studied and isolated by me up to the present time are the following: *Alternaria polymorpha* Planchon, *Alternaria charterum* Preuss, *Stemphylium piriforma* Bonord, *Cladosporium herbarum* Link, var. *fimicola*, *Strachybotrys atra* Corda, *Acrostalagmus cinnabarinus* Corda, *Spicaria elegans* Corda, *Aspergillus repens* de Bary, *Cepha lothecium roseum* Corda, variety B. Matr., *Fusarium* sp., *Stysanus stemonitis* Pers, *Chætomium Kunzeanum* Zopf.

Among these species some have a blackish pigment: *Alternaria polymorpha*, *Alternaria chartarium*, *Stemphylium macrosporoideum*, *Stemphylium piriforme*, *Stysanus stemonitis;* others are greenish-black: *Strachybotrys atra;* others a deep chestnut: *Stemphylium botryosum*; and still others a brownish-grey, *Cladosporium herbarum*.

Others yet secrete an ochre coloring matter: *Acrostalagmus cinnabarinus;* or rose, *Cephalothecium roseum*; or cherry-red becoming in the course of time "dregs of wine" and rust color, *Fusarium;* apple-green, *Chætomium Kunzeanum;* brownish-yellow, *Aspergillus repens* light brown, or chestnut, *Spicaria elegans*.

These are the pigments secreted by all the fungi which I have just named which produce the specks on paper.

*A report at a recent Session of the French Academy of Sciences.

[2]For a full discussion of this see pamphlet by F. J. Hoxie entitled, "Dry Rot in Factory Timbers," published by the Associated Factory Mutual Fire Insurance Companies, Boston,

Appearance and Disappearance of Islands in the Pacific

PROF. MACMILLAN BROWN, in a recent number of the *Press* of New Zealand, discusses the appearance and disappearance of islands amid the western insular fringe of the Pacific. He recognizes two curves of vulcanism, an outer, extending from the Aleutian Islands to Malay and New Zealand, and an inner, passing through the Marianne, Caroline, Gilbert, Ellice, Samoa, Tahiti, and Paumotu archipelagos to Easter Islands. The outer curve lies off the enclosing continental shelf of the ocean, while the inner curve is parallel with the trend of the ancient continental shelf. The "main longitudinal crescent of vulcanism" has shifted from the inner to the outer curve, and with this shifting much archipelagic land between the two curves has disappeared. The main interest of the theory lies in the suggestion that this shifting has taken place in human times. The elevation of Rota on the N. Mariannes is dated to the Japanese Bronze age, 4,000 years ago, by bronze bosses in the elevated coral. Ocean Island has risen and sunk several times, and in a previous elevation was inhabited by Polynesians, who made the regular Maori ovens. Ponape is supposed to have been a central point in a large archipelago with a great population. A considerable forest area with a dense population is required to account for the megaliths of Easter Island. In any case, those who speculate on migration routes must not assume as their basis the same areas and distribution of land in the Western Pacific as now exists. Prof. Brown, if the subsidence theory of atoll formaton (which he assumes to be the only applicable theory) is applicable to the Western Pacific, must find much further and more direct evidence of those great archipelagos which he postulates as existing such a short time ago in what are now deep oceans with comparatively level beds. Existing coral formations do not point to the former existence of great islands. The animals and plants of still existing high lands should be more varied in genera and species if such lands were formerly parts of considerable archipelagos.—*Nature*.

Life on Glaciers and Snow Fields

Animals and Plants that Flourish Amid Snow and Ice

By Titus Ulke

GLACIERS and snowfields are by no means normally barren of life, as is commonly supposed.

My interest in this subject was first aroused, years ago, upon observing plants, of many different species, growing through and even flowering below the snow crusts clothing the slopes of Mont Blanc, in Switzerland, and on the Ortler, in the Tyrol, and again last year, in seeing acres of so-called "red snow" and abundant animal life flourishing on the snows and glaciers of Mt. Rainier.

Let us first consider the *snowfield* and *glacier worms* (which belong to the order *Oligochæta*) found on Mt. Rainier.

In August of 1916 I had the pleasure of visiting the habitat of these interesting forms of alpine life with Prof. J. B. Flett, who gathered the material for a monograph published in April, 1916, by Paul S. Welch, entitled "Snowfield and Glacier Oligochæta from Mt. Rainier," Contribution No. 18, Kansas State Agricultural College, from which some of the following notes were derived.

There are at present known in the world approximately sixty species and varieties of snow and ice worms, all of which belong to the genus *Mesenchytraeus*, of which twenty-one species and three varieties are recorded from North America and are practically all confined to the Pacific slope. Five species and two varieties occur in California; at least two species are found in the State of Washington, while the balance, with one or two exceptions only, are restricted to the mainland and islands of Alaska and are not definitely known to occur elsewhere.

Prof. Russell appears to have been the first to observe such worms on the snows of Mt. Rainier. Two species found there have thus far been described: *Mesenchytraeus gelidus*, Welch and *Mesenchytraeus solifugus*, var. *rainierensis*. The first of these is illustrated in Fig. 1 of the accompanying sketch. Sexually mature specimens, yellowish to a dark reddish-brown or black in color, about an inch long and 1/20 inch in diameter were found in February and April abundantly on the open snowfields of Mt. Rainier, at an elevation of from 2,700 to 5,600 feet above sea-level. They also occurred on the snow on the mountain slope protected by a dense forest of fir and hemlock. These worms have not thus far been found on solid ice nor on the glaciers, though they occur on the snow below the ice-front, and outside of the lateral moraines, of the Nisqually Glacier. The snow on which they were found is not permanent through the entire season, but melts with the coming of summer, and it therefore appears that a part of their life must be spent *on* or *in* the ground. During midwinter, when the temperature is very low, they are inactive and do not appear on the surface of the snow. Appearance at the surface accompanies the rising temperature in the spring, and their activity becomes noticeable when the snow is beginning to melt. When placed on hard packed snow during their active period, they are able to bore down through it at will. Under conditions of softening snow they exhibit a rather efficient locomotion. When taken in hand, they perform lively squirming movements for a time, but soon relax and become quiet. Bluejays and several other species of birds prey upon these worms, picking them off the surface of the snow.

Nothing very definite is known concerning the food of these snow worms. Prof. Flett reports that the snow over which these enchytraeids crawl usually has a red color, due to a minute, unicellular plant which, in his opinion, serves as food for the worms. Prof. Welch found a considerable quanity of such microscopic algæ, composed of very minute, globose cells, containing greenish and reddish pigments, occurring singly or in clusters, in the alimentary canal of these worms, thus leading to the conclusion that these snow algæ constituted a large part of their food.

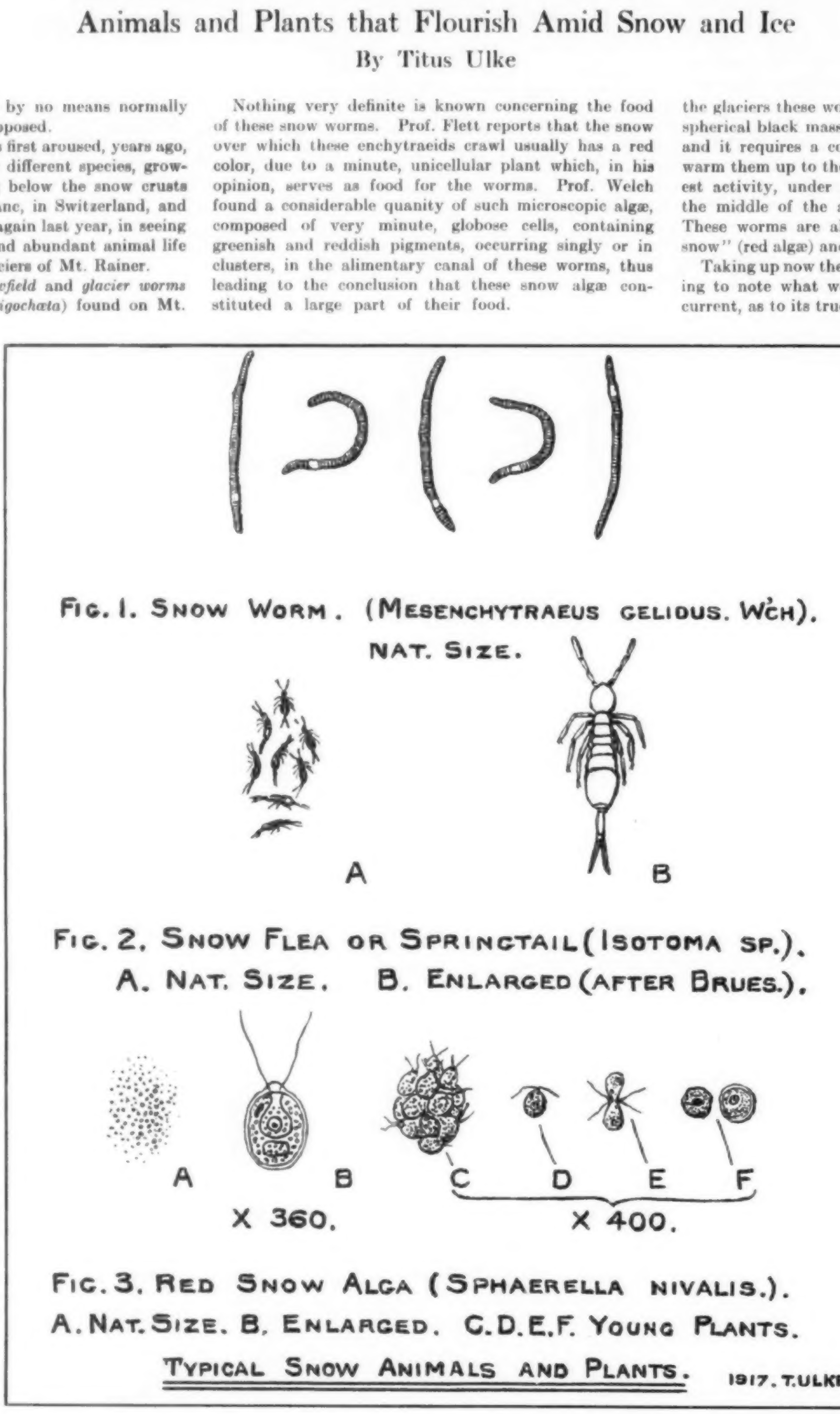


FIG. 1. SNOW WORM. (MESENCHYTRAEUS GELIDUS. W'CH). NAT. SIZE.

FIG. 2. SNOW FLEA OR SPRINGTAIL (ISOTOMA SP.). A. NAT. SIZE. B. ENLARGED (AFTER BRUES.).

FIG. 3. RED SNOW ALGA (SPHAERELLA NIVALIS.). A. NAT. SIZE. B. ENLARGED. C. D. E. F. YOUNG PLANTS.

TYPICAL SNOW ANIMALS AND PLANTS. 1917. T. ULKE

In the same habitat with the snow worms, the writer found numerous species of insects, many of which were probably carried there by air currents or strong winds, belonging to eight orders: namely, Collembola, Hemiptera, Plecoptera, Coleoptera, Diptera, Lepidoptera, Orthoptera, and Hymenoptera and three species of spiders.

The snow fleas or springtails, belonging to the class *Collembola* and genus *Isotoma* are shown in Fig. 2. They sometimes occur in enormous numbers, possibly in billions, especially on the snow below the galciers, making it grey or even black in appearance over large areas.

Mesenchytraeus solifugus, var. *rainierensis*, Welch, was found by Prof. Flett in June on the upper snowfields of Mt. Rainier, at an altitude of 7,500 feet. It is blackish in color, but about half the size of *gelidus*. Worms of this variety occur on snowfields which seldom thaw during the summer, and they evidently pass their entire existence, generation after generation, in the snow and ice. There are reasons for believing that they may be found to live at an altitude as low as 6,000 feet. On the glaciers these worms coil up so as to appear as small spherical black masses or dots on the snow or solid ice, and it requires a considerable exposure to sunshine to warm them up to the active stage. The period of greatest activity, under normal conditions, is usually from the middle of the afternoon to about 5 or 6 o'clock. These worms are also associated with abundant "red snow" (red algæ) and with snow fleas.

Taking up now the subject of "red snow," it is fascinating to note what weird notions have been, or still are current, as to its true nature.

Some early explorers considered the alga a *fungus*, others stated that it was merely *volcanic dust*, some scientists described it as a *rotifer* or *infusorian* or *crustacean*, and still other observers believed that *it was the real blood of certain departed saints*.

The red snow alga, known as *Sphaerella nivalis*, and illustrated in Fig. 3, has received eighteen different scientific names, according to the belief prevailing at any given time and place as to what it really was, to wit:

Sphærella lacustris, Witte.
Volvox lacustris, Girod.
Sphærella nivalis, Sommerf.
Chlamydococcus pluvialis, (Flot.) A. Braun.
Hæmatococcus pluvialis, Flotow.
Hæmatococcus Cordoe, Menegh.
Hæmatoccus mucosus, Morren.
Protococcus pluvialis, Kuetz.
Protococcus monospermus, Corda.
Protosphæria pluvialis, Trevis.
Protosphæria Cordoe, Trevis.
Chlamydococcus nivalis, (Bauer, Ag.), A. Braun.
Hæmatococcus nivalis, Ag. Icon.
Hæmatococcus Crevillii, Ag. Icon.
Coccophysium nivale, Linke.
Palmella nivalis, Hook.
Tremella nivalis, Robert Brown, and *Chlamydomonas nivalis*.

The above list of synonyms with one exception, was taken from DeToni's review of the species and was kindly furnished, together with a reference to the articles cited below by Dr. K. Kellermann of the U. S. Bureau of Plant Industry.

The earliest mention of "red snow" of which I could find a record was by Francis Bauer, in a report made in 1820 to the Royal Society of London (Philos. Trans. Part I, 1820, Pages 165-178) on the "red fungus" which was found to color the snow discovered extending over a range of cliffs in Baffin's Bay by the polar expedition under Captains Ross and Kane in 1818. Bauer performed some experiments with the so-called "fungus" and found that cultures of it remained colorless at the top of the original red sediment employed. He stated that the full grown red fungus is a gelatinous mass, densely filled with spherical membraned cells, between 1/1600 and 1/1200 of an inch in size, and containing numerous red and green granules, and concluded that while excessive cold, such as 26 F. below freezing, and exposure to sharp air and wind, may kill the primitive fungi, their so-called seeds still retain sufficient vitality to vegetate and propagate, *if immersed in snow*, which appeared to be the natural soil of these peculiar fungi.

In 1880 Prof. J. Brun reported to the Belgian Microscopic Society (Bulletin V. 1880, Pages 57-61) on a "Shower of blood which fell in the summer of 1878"

on the holy mountain of Djebel Sakra of the Atlas range in Morocco. The natives observed the red shower on the said mountain, which is an isolated mass of rocks, virtually bare of vegetation, rising to a height of 8,500 feet, and affirmed that it was *the veritable blood of the saints which had once inhabited that locality*. By employing strategy, owing to the superstition of the natives, Brun managed to visit the region, sacred to Islam, and collected specimens of the blood red material, which closely covered or spotted the rocks, shrubs, and lichens at about 7,500 feet elevation, for a space of many hundred acres. He reached the conclusion, after microscopic examination, that the red color was due to a young and undeveloped *Pleurococcus fluvialis* mixed with organic debris and considerable very fine calcareous or alabaster-like sand. It was probably carried, Brun states, either from the snowy slopes of the Atlas mountains or it consisted of mud from the dried-up brackish lakes to the southward, which had been observed to contain similar red algæ, carried along by the dry winds from the southeast and precipitated by moist west winds proceeding from the Atlantic. Growth of the alga was at first given a tremendous stimulus by the heat and moisture and mud mixed with it, but was soon checked by the normal dryness of the arid environment. The natives stated that two similar down-pours of "blood" had been observed in the course of the previous decade.

In 1881 R. B. Craft (Trans. Hertfordsh. Nat. Hist. Soc. 1881, pp. 170-172) noted that examinations of the "red snow" obtained in 1839 at Grimsel and in 1840 at the Aar Glacier of Switzerland, led Prof. Agassiz and others in 1841 to conclude that the coloration was due to immense numbers of moving animalcules and *eggs of the rotifier Philodina*, and Prof. Meyer in 1848 to remark that the cause of the red and green snow found on Spitzbergen was due to infusoria, namely, *Euglena sanguinea* and *Euglena viridis*. Craft also noted the occurrence of "red snow and ice" in 1881 in Hertfordshire.

Charles Hallock in 1886 in an article that appeared in the Amer. Monthly Micros. Jour. v. 7, 1886, p. 42-43, stated that all the observations of naturalists point directly to the higher mountain slopes or glaciers as the birthplace of the plant from which the red deposits originate. In 1860 he and Prof. Elliott Coues, while cruising along the Labrador coast, in latitude 53°, saw a large gothic iceberg of opaque dead white, whose facade was crossed by a transverse vein of brilliant crimson, which color was evidently caused by the same red deposit originally formed on the topmost stratum of the glacier from which the iceberg had broken loose.

In 1881 M. Thoraude communicated a note on a supposed shower of blood which fell on December 13, 1887, at Tay-Ninh, in Cochin-China, to the Paris Academy. (Comp. Rend. v. 106, 1888, pp. 779-780). While riding toward his home in a public conveyance together with several fellow travelers at that time he was suddenly accused by the angry young Malabar driver of having spread blood over his (the driver's) white linen clothes. It was immediately noticed, however, that similar drops of alleged blood covered the others' clothes, and that the heavens were darkened with dense humid clouds but that no rain fell. The natives recalled, with superstitious terror, previous showers of blood or "water that was changed into blood." As to the cause of the phenomena mentioned, Blanchard stated that Payen in 1836 attributed the red coloration to a minute crustacean branchiopod, to wit, *Artemisia salina*, which was probably transported, he thought, by wind and storm from the neighboring salt marshes.

A really accurate description of the red snow alga, *Sphærella nivalis*, finally is found in the American Botanist of 1912 v. 18, pp. 33-35. It is therein noted, by S. B. Parish, as a common alga in 1911 on the snow of the peaks above the Yosemite Valley, California, a phenomenon usually rare below the Arctic Circle and never before reported on this continent so far south in latitude. No other living organism appears to be able to endure such extremes of temperature as these algæ. The "red snow" plant certainly leads a hard life. It remains dormant during the long arctic winter, but the summer awakens it to activity.

A consideration of the structure and methods of reproduction of this alga may well explain its marvelous capacity for multiplication and spreading over large areas of ice and snow with comparatively incredible rapidity.

The alga is a free swimming cell with the cell membrane closely applied to the protoplast, at the anterior end of which two hair-like organs or cilia, for swimming and other purposes, and a red eye-spot are situated. It is characterized by the presence of a red pigment (hæmatochrome) in the cells. Reproduction is both *asexual*, by means of swarm spores, 2-8-16 of which are formed in a mother cell, and *sexual*, by conjugation of similar, small, biciliate gametes formed in large numbers (up to 64) in a mother cell, and uniting in pairs by their anterior ends to form a zygote. Thus the alga has several modes of multiplying its kind with great rapidity, and its transportation by wind and water and attachment to the feet of birds and other animals is facilitated by the long cilia with which each mature individual and each swarm spore is provided.

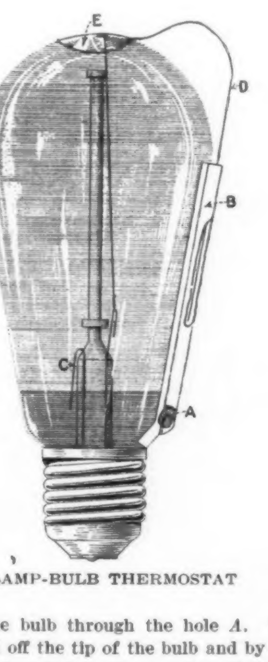
Besides "red snow" there are found in various parts of the world, "brown snow," "green snow," and "yellow snow," each owing its color to the presence of a different alga. Nor does this exhaust the richness of the snow flora, for even seventy species of plants, almost all of which are algæ, grow in snow and ice.

Among higher plants, found growing in the border snow and glacier debris, at or above timber line, may be mentioned the lovely purple bell-flowered *soldanella* and the *pinguicula*, with its insectivorous leaves, the pink-flowered *Ranunculus glacialis*, numerous kinds of *saxifrages*, *potentillas*, white and yellow *erythroniums*, lovely alpine or dwarf *lupines*, pinks, heathers and numerous species of *crucifers*. Among the latter I found the yellow-flowered hairy *Draba aureola* and the white-flowered *Smelowskia ovalis* growing near Camp Misery, on Mt. Rainier, at an elevation of over 12,000 feet. In the lava-lined crater at the summit at about 14,400 feet above sea-level, I noted a *Grimmia* moss and at least two kinds of lichens.

In concluding this paper, I will call attention to a few only of a large number of birds and mammals which spend at least a portion of their life on the alpine or Artic snows or on glaciers. Typical examples are the white ptarmigan, certain humming birds, of which I noted many specimens flying over the Nisqually glacier, evidently feeding on the insects crawling upon it, Canada jays, snow buntings, snow-shoe rabbits, ermine, white foxes, bears, mountain goats, mountain sheep and a host of other animals which eke out a scanty existence either by browsing on the lichens, grasses or sedges, which often border the snow and ice-fields, or by feeding on the afore-mentioned worms, insects and other animals living on or blown onto the ice and snow by wind or storm.

A New Use for Old Lamp Bulbs

THE contact-making thermostat shown in the figure depends on the contraction and expansion of air in a bulb forcing mercury up a tube and closing an electrical circuit. A 1/8-in. hole *A* is made in the bulb of a 25-watt Mazda lamp near the base. A tube *B*, consisting of shellacked paper, is then formed on the side of the bulb, with the upper end open and the lower end



LAMP-BULB THERMOSTAT

leading into the bulb through the hole *A*. The next step is to grind off the tip of the bulb and by means of a No. 14 wire inserted in the opening, the leading-in wires from the base are bent, one straight down and the other with a hook, as shown. A piece of No. 22 wire, with a loop on one end is looped over the hooked leading-in wire and then drawn up through an opening in the top of the bulb and allowed to extend out about 1 in. The top opening is now sealed over with a piece of shellacked paper *E*. Enough mercury is put in the bulb so that the leading-in wire *C* dips into it 1/4 in., then the lamp is screwed into a receptacle, and wire *D* coming from the top of bulb is bent down into tube *B* so that the circuit will be closed at the desired temperature.

A contact, sliding in clips, may be used instead of the bent wire if a more elaborate arrangement is wanted.—*C. V. Hawbecker, in Power.*

The Pendulum Tank for Testing Ship Models

A CORRESPONDENT of the *Engineering Supplement* of the *London Times* has the following to say in relation to a form of tank for investigating the properties of ship models for which he claims special value:

"It was to Mr. A. H. Haver, a naval architect, of Newcastle-on-Tyne, that the tank disclosed its secrets, and the inspiration of the tank first came to Mr. Frank Caws, of Sunderland, who in 1893 read a paper at a meeting of the North-East Coast Institution of Engineers and Shipbuilders on "Certain principles of motion as taught by the pendulum, together with a brief sketch of the pendulum speed power meter"—in other words, the Caws pendulum tank. This consists of a pendulum swinging over a tank of water; the model is propelled by a free attachment to the bob of the pendulum and is drawn horizontally through the water as the pendulum swings radially. The amplitude of the swing is inversely proportional to the resistance of the model, and the arc of swing gives the resistance. In his paper Mr. Caws claimed for his tank the power of determining the absolute resistance of ships' models. Some of those taking part in the discussion on the paper were not prepared to admit this claim, but it was generally agreed that the performances of the ships were in very close agreement with the results of the experiments carried out by Mr. Caws with their models in his tank.

Mr. Haver made experiments in the tank with models of the corrugated ship, and obtained results in the ships built on his experiments which agreed almost exactly with the promises of their models. He ran a model with plain sides and got a certain result due to a certain amplitude of the swing of the pendulum. He then put corrugations on the model and ran it again, fully expecting that the swing would be reduced on account of the increased wetted area due to the corrugations. But, to his surprise, the swing of the pendulum was increased, proving that, though the wetted area was increased, the resistance was by some means decreased. The result was so startling, and so opposed to all existing theories, that he could not at once believe it, and looked for error in his methods. No error was to be found, the results were repeated, and the corrugated ship was discovered.

While it is not suggested that the Froude tanks should all be immediately closed and Caws tanks substituted, it is suggested that the Caws tank would be a valuable supplement to the Froude tank, and might eventually take its place. A Froude tank is anything from 300 feet to 500 feet long (Berlin has one over 1,000 feet), and the cost of installation runs into tens of thousands of pounds. A Caws tank could be fitted up in one of our dock-yards, or some public building, for perhaps £200, provided headroom of 50 feet to 75 feet could be found with, say 100 feet by 40 feet of floor space. What the staff of a Froude tank is composed of, I do not know, but salaries and upkeep must run into thousands of pounds a year. Mr. Haver has for years run the Caws tank single-handed, the expense of its upkeep being nominal. The run of a model in a Froude tank takes a considerable time, and the calculations of the results, such as they are is difficult. I understand that the cost is in the neighborhood of £100.

A model of a corrugated ship has been run in both tanks. The results of the Caws tank trials were realized almost exactly in the ship, while those got from the Froude tank were some 20 per cent wrong. The fact that the Caws tank succeeded where the Froude tank failed must be known to many, and was brought to the notice of the Admiralty, but no inquiry would appear to have been made. Figures of a month's trip in one of the corrugated ships were submitted to one of the greatest authorities on these things in this country. The records submitted I had myself seen made at sea, and I was, therefore, in a position to guarantee them; but they were somewhat contemptuously refused consideration, because it was declared they were "contrary to theory." A different attitude of mind was shown by Lord Rayleigh, who, referring to the same results, wrote: "All I would say is that the theory of skin friction is not so well understood as to justify a positive rejection of results which may have an experimental foundation."

The patent rights of the Caws tank have long since expired, so that it is open to the world. The present pendulum is only 19 feet, and the tank is about the same length. In more extended use, especially with high-speed trials, it would probably be necessary to increase the length of the pendulum to 50 feet or more, and the tank in proportion. It is believed that the pendulum could be equally successfully applied to the determination of the resistance of aircraft of all sorts."

Calico Printing*

Its Origin and Development

By Robert Reoch

My experience in the calico printing business extends over a period of fully 60 years, and embraces many of the great changes which have occurred in the art of printing, both in the chemical and mechanical departments of a print works.

Within my recollection, block printing had reached its highest development, and it was not steam power, but Dame Fashion, that dealt the final death blow to printing by hand. This at least was true as regards Scotland, where shawl printing continued to flourish up till 1855, and even later.

Calico printing is at once a fascinating and perplexing business; new problems are continually presenting themselves which demand attention and keep the printer keyed up constantly to concert pitch. It embraces in its operations the highest mechanical skill, the most wonderful chemical transformations, and the sublimest art, in creating original designs and harmonious blending of colors. Broadly speaking, calico printing rests on the triple foundation of art, chemistry and mechanics, and yet again in its practical operation it is subdivided into three distinct branches—the preparation of the cloth, the engraving of the patterns, and the mixing of the colors.

These are all very different and entirely independent of each other, and, indeed, across the water it is not uncommon to have them done at different establishments. At the printing machine these separate units come together for the first time. With this brief general introduction, I shall proceed more methodically to the consideration of the subject in detail.

As already intimated, the coloring of fabrics by dyeing or painting is practically coeval with the human race itself, and all the nations of ancient times of whom we have any record make frequent reference to it. The first reference to dyed fabrics in the Bible is in the book of Genesis, the 37th chapter in that simple drama of human life as set forth in the story of Joseph and his brethren, where it speaks of Joseph and his coat of many colors. The second and more specific mention we find in Exodus, the 25th chapter, where it speaks of blue, purple and scarlet, and fine linen for the adornment of the tabernacle, and elsewhere we find in the Old Testament reference to the Egyptians as being skilled in dyeing. This is borne out by other ancient writers, particularly Pliny, in his Natural History, written in the first century of the Christian era. Historians are generally agreed that the Egyptians acquired their knowledge of the art from the East Indies. It was also well known in Persia and China from time immemorial. At first the designs painted by hand on the fabric were very crude, but a gradual improvement took place, patterns became more refined and elaborate, and different nations in their designs and colorings had distinct characteristics by which they could readily be identified. For ages this crude and laborious method of producing designs on cloth was in use.

When and where the first great step in advance was taken from hand painting to stamping or the use of blocks is shrouded in mystery. India and China are usually credited with this invention, and as may be supposed, the blocks in those primitive times were clumsy in the extreme. The method of getting the pattern on the blocks was by painting the design on a slab of wood, then all the unpainted parts of the wood were cut or chipped out, leaving the design in relief. In later times the design was built up on the face of the block, the finer or more elaborate parts of the design were obtained by thin pieces of copper of varying lengths and widths driven into the wood, and the solid or heavier parts of the pattern were filled in with felt. Such blocks were more durable and less liable to injury. Patterns might consist of one or more colors, but required a separate block for each color. To state it briefly, block printing was done on precisely the same principle as the stamp and pad in common use today, but on a larger scale. Blocks were usually ten to twelve inches square, so that with a block 12 inches square it would require 450 impressions to print a piece 50 yards long and one yard wide, and if it should happen to be a four-color pattern it would then mean 1800 impressions. It would take a very smart printer to print two impressions per minute, making allowance for changes, etc. This would mean 15 hours for 1800 impressions, whereas a cylinder printing machine could readily do the same number of yards in one and a half minutes. This gives an idea of the immense gain in product since the introduction of the cylinder printing machine, and for many classes of fine work the difference in quality is almost as marked.

In the year 1769, the steam engine was put into practical shape and patented by James Watt. This gave a wonderful impetus in a few years to many lines of business, and among others to the textile industries, and placed Great Britain at that time in the lead as an industrial nation. Calico printing also offered an inviting field for the application of steam power, and many patents were taken out to supplant the slow process of block printing by hand. Three of these methods adopted in Great Britain are alone worthy of mention and continued in use for at least 75 years after the invention of the present method of cylinder printing. The first of these was invented by a Scotchman named Thomas Bell in 1770. Bell's method was called the plate printing or flat press process; it consisted of a copper plate 36 inches square and ¼ inch in thickness, on which the pattern was engraved by hand. The very finest patterns could be engraved in this way, very much more delicately than could be done by block work. The mode of operation was very similar to letter press printing, except that in the latter the letters or figures are in relief, whereas on the copper plate the engraving is under the surface. The color was spread over the copper plate with a brush, but the great difficulty was to remove the color from the surface of the copper without removing it from the engraved parts. Finally, after much experimenting, the difficulty was overcome by using a steel blade, which ever since has been called a doctor, as that remedied or doctored the difficulty; but it can readily be seen that this was not continuous printing; it could be used for handkerchiefs only, and was limited to printing one color. This was overcome later, for as the fabric passed from the copper plate it was spread on a table where other colors were blocked in by hand. In the town in Scotland, quite a printing center, where I lived as a boy, two of these flat printing presses were in use up to 1855. At that time they printed silk handkerchiefs only, mostly in two colors. Letter press and lithographic printing are done in sheets, and up to the invention of copper cylinder printing, calicoes were practically executed in the same manner, but the great desideratum was to make it continuous, and have the pattern continuous. It was soon recognized that this could only be accomplished by having the patterns on a cylinder, and the most natural method to follow was to have blocks cut on a wooden drum or cylinder. Many patents following this plan were taken out, both in Great Britain and France. It was also the most natural thing in the world for this same Mr. Bell to have his copper plates rolled into circular form and brazed at the joint; his cylindrical roller was then complete, and continuous printing an accomplished fact. So, in 1783, Bell, who was then in the employment of an English firm in Lancashire named Livesey, Hargreaves & Co., took out patents for a six color printing machine, which was followed by other patents in succeeding years.

It is worthy of remark that while it took thousands of years to develop the art of calico printing from primitive methods to the machine invented by Thomas Bell, the essential features of his invention remain practically the same.

We now come to engraving, which is a most important part of calico printing by copper rollers. At first it had all practically to be done by hand, and was necessarily a very slow process, but produced very beautiful work. It resulted, however, in a limited variety of patterns, even with a large force of engravers. Something must be done, human ingenuity was evoked, and very soon numerous patents were taken out; many of them with little merit, which we cannot even name. I will refer to only two methods which have survived, which cover entirely different fields, and have been developed to a high degree of perfection.

The first of these is called machine engraving, and embraces all the finest and most delicate class of patterns, and may be compared to steel engraving. By this method a small piece of round, soft steel, called a die, is engraved by hand, and the amount of engraving is reduced to the minimum. After engraving, the die is case hardened by tempering, another piece of soft steel about three or four times larger in circumference, called a mill, is then taken; and these two pieces of steel are placed in a vertical press and made to revolve against each other under a pressure of several tons until the soft piece of steel called the mill is forced into the engraved parts of the die. This brings the pattern out in relief on the mill, which is then case hardened and ready to be transferred to the copper roller. The latter must, of course, be an exact multiple in size of the mill—that is, if the mill is 4 inches in circumference, the roller would have to be 12 or 16 inches in circumference. The roller is then placed in the engraving machine and made to revolve with the mill pressed against it until the mill sinks deep enough into the copper to make a good impression. This is repeated until the whole roller is engraved, which in most cases requires but a few hours.

The other method of engraving, which is more commonly in use for the great majority of patterns, is called pantograph engraving. This class of engraving began to be used about 1860, and was the subject of numerous patents. By this process there is very little hand engraving, and may be explained briefly as follows: A careful drawing of the pattern is made; this is placed in a camera, and thrown down on a thin zinc plate enlarged five times. The pattern thus enlarged is engraved or etched, and when ready to be transferred to the roller the latter is covered with a fine coating of varnish and placed in the pantograph machine, which has a bar containing a diamond point for each repeat of the pattern across the face of the roller. The machine is so arranged that when the operator traces the pattern on the zinc plate each separate diamond traces and reproduces the pattern on the varnished roller, but brought back to the original size of the pattern, hence the name pantograph machine. Be it specially noted here, however, that this process does not actually engrave the roller, the diamond points simply scratch off the varnish; and when the roller is all traced over it is taken to an etching trough where it is slowly revolved in a bath of nitric acid for a few seconds until the engraving acquires the proper depth to print well.

I have thus given very briefly a bare outline of the process of engraving. I would simply add that photography is beginning to play an important part in preparing designs for engraving, and much progress has been made in this direction within a few years. Many other devices might be named which have been introduced of late, and all with this great three-fold object in view—better results, shorter time and less cost.

There are a few things that the leading printers on the other side have adopted which I had the privilege to observe, a few months ago, and which might be adopted here by our printers to advantage. The first I would name is blanket washing, which effects a great saving by dispensing with black grays. The second is having machines wide enough to print two widths of cloth at one operation. The third and most important is the use of electro-plated copper rollers on iron centers. Such rollers on an average have not more than 25 pounds of copper, whereas solid copper rollers run from 100 to 150 pounds each. This electro-plating has frequently been tried here, but without success. It is done there, and it can and ought to be done here, and the saving would be enormous in several ways.

Before closing the mechanical branch of the subject, it may be interesting to note that 50 years after cylinder printing had come into general use on the other side of the ocean, block printing had a wonderful revival in a class of work that could not be attempted by cylinder printing. I refer to shawl printing in imitation of woven cashmere and Paisley shawls. The shawls were single and double; the single shawls were 6 feet square, the double 6 by 12 feet. One can therefore understand that printing machines could not be built or copper rollers made of such enormous dimensions; therefore block printing flourished until 1860. Then came a change in fashions; shawls and plaids gave place to jackets, coats, cloaks and mantles, and this proved a crushing blow to block printing from which it has never recovered.

East Greenwich, in Rhode Island, has the honor of being the birthplace of calico printing in the United States, and it seems to have become more firmly established in Rhode Island and around Philadelphia than anywhere else toward the close of the eighteenth century.

I will now proceed to consider the second part of the subject, viz., the development of calico printing from the chemical standpoint, and that of course relates more especially to the coloring department. Though the mechanical development has been marvelous, it is hardly to be compared with the amazing progress made in the production of new colors. Until about fifty or sixty

*From a paper read before the National Association of Cotton Manufacturers.

years ago, vegetable dyes, with a few exceptions, were almost exclusively in use, and many of the methods employed were both crude and tedious in the extreme.

No doubt most of you are familiar with the names of the old vegetable dyes, such as logwood for blacks and purples; madder, sapan-wood, Lima wood and barwood for reds and pinks; fustic, quercitron bark, Persian berries and annatto for yellows and oranges; cutch and catechu for browns; indigo for blues. Many others might be named, but these were most commonly in use. We must not overlook cochineal, from which the brilliant scarlet for military coats was produced. This, however, was not of vegetable origin, but was a small insect carefully propagated in Mexico. Quite a number of mineral colors also began to come into use within the last 150 years, which were unknown to the ancients, such as chrome yellow, chrome orange and Prussian blue, etc.

Those dyes and colors which I have just named comprised about all the materials that the calico printer had at his command 60 years ago; but let me at this point call attention to a singular fact—cotton goods have no affinity whatever for these vegetable dyes. The goods may be boiled in these dyes, but they will not absorb or develop the coloring matter of the dye, and some of the fastest and most valuable of the aniline colors called basic colors possess the same characteristic. Silk and wool on the other hand have a great affinity for nearly all coloring matters, and absorb them with great avidity. How is this difficulty to be overcome?

It has been found that certain salts which possess no coloring properties whatever in themselves have a great affinity for cotton goods on the one hand, and on the other a great affinity for the vegetable dyes; and colors dyed in this way are usually the fastest colors we have. Take, for example, the old genuine Turkey red and the old Merrimack pinks and purples of 50 years ago.

Please note carefully this other most remarkable fact that a variety of those colorless salts, which are called mordants, may be printed on the same piece of calico, and when dyed together in the same dye bath, will come out in a variety of different colors. It may be interesting to note that this method of mordant dyeing was known to the ancients. Pliny, the elder, in his Natural History, a most voluminous work written in the first century, gives as clear and concise an account of this method of mordant printing and dyeing as could be written by any expert to-day. Listen to this translation of a short extract from Pliny:

"There exists in Egypt a wonderful method of dyeing, the whole cloth is stained in various places not with dyestuffs but with substances which have the property of absorbing colors. These applications are not visible on the cloth, but when the pieces are dipped into a hot cauldron containing the dye the remarkable circumstance is, that though there be only one dye in the vat, yet different colors appear on the cloth which cannot afterward be removed."

If time permitted I would like to quote further, but must forbear. This shows conclusively that the ancients were familiar with this method of dyeing.

I might state here that alumina in solution will produce red or pink according to strength of the solution. Iron in the form of pyrolignite of iron will dye a black or lilac according to strength; solutions of tin give shades of orange and yellow, and various shades of chocolate and brown can be obtained by mixtures of these solutions with the addition of other materials, all of these shades being dyed at the same time with alizarine.

When the writer came to this country in 1867, just 50 years ago, fully 80 per cent of the calicoes were printed in this way. To-day there is not a single print works here or abroad that does this mordanted class of work—yet some beautiful work was done by this method. Still, amid the immense variety of shades produced by mordanted work, we could not produce a bright blue, green, yellow or purple. The result was that for many years block printing continued as an auxiliary to machine printing, for blocking in some of these bright colors after dyeing. This state of things continued to exist until the advent of aniline colors, when the art of block printing received its quietus.

About 1845 the French introduced a new class of work, called the pigment style, which from its simplicity and ease of application soon came into universal use in France and Great Britain. This class of work is founded on the fact that when white of egg is subjected to heat it coagulates. Various pigment colors, such as ultramarine blue, chrome yellow, chrome orange, guignet green, and a host of other colors, are simply mixed with white of egg in the liquid form and printed. They are then subjected to steam at a pressure say of five or six pounds, the albumen of the white of egg coagulates and imprisons the pigment colors, and the colors thus fixed are very fast indeed. Albumen in its purest form is obtained from eggs, but on account of its cost various attempts were made to obtain it from other sources, until at last it was successfully obtained from blood of oxen and other animals at about one-fourth of the cost, and it is now very largely produced in the United States.

In 1856 a great impetus was given to calico printing and dyeing by the discovery of aniline violet by a young English chemist named Perkin. This discovery laid the foundation of the coal-tar color industry, which in its results has been as profound and far-reaching as any event in human history when we consider the ever extending uses to which coal-tar products are being put.

In a few years after this discovery of aniline violet, there followed in quick succession other discoveries of different colors, until the whole range of colors in the chromatic scale was at the command of the colorist, causing a complete revolution in the printing and dyeing industries; but amid all the discoveries of so many brilliant colors, we had not what might be termed a perfect black. It was left to Mr. John Lightfoot of Lancashire, England, in 1863, to make this crowning discovery and give a black that covered all the requirements, and may be regarded as the type of all fast colors; but, like most other good things, there were difficulties in its application which caused much trouble. I might say that it was to introduce and work out this problem that brought me to the United States in 1867.

The discovery and application of aniline black effected many changes in the art of calico printing, and has been the subject of more patents and controversy than all the new colors combined. Although at first very difficult to handle with the chemicals at the colorist's disposal, it is now one of the simplest to produce, and to-day holds a more important place than any other color or class of colors in the whole range of coloring materials.

In 1869 the industrial world was again startled by the wonderful discovery of artificial alizarine by two German chemists named Graebe and Liebermann. Alizarine is the coloring principle of madder root, a plant indigenous to many countries in Europe and Asia and well known to the ancients. Fifty years ago madder was a very important article of commerce in this country, and was imported in vast quantities from France and Holland, where it was chiefly cultivated; today I doubt if a single ounce could be found in the whole country. Turkey reds had been made from madder from time immemorial, but the introduction of the artificial article in a purer and more concentrated form, made from coal-tar products, caused a complete revolution in established methods. It greatly simplified the process of producing Turkey reds and other fast colors of this type, and opened a place for itself in other lines of work from which it had hitherto been shut out. It enabled printers in this country to do Turkey reds, bandanna handkerchiefs, and other classes of work, which hitherto had all been imported.

Take for example, bandanna and other Turkey red handkerchiefs. When we started printing them here, the retail price was 20 cents to 25 cents each according to size. Within a year or two, the price gradually declined to 7 cents each, and finally to 5 cents, and even at that it was quite a profitable business.

In 1878 the industrial world was again electrified by the discovery of artificial or synthetic indigo, but it took about fifteen to twenty years before the article could be produced on a commercial scale at a price to compete with natural indigo.

Today vegetable indigo is practically driven from the market. This is an example of the great aim of modern chemistry to imitate nature and produce natural products by chemical processes in the laboratory; and not alone in the laboratory, but on a vast commercial scale.

Nearly all our dyeing materials are produced in that way today, and in such a concentrated form that often there is as much pure coloring matter in a small phial as used to be contained in quite a large package. Be it noted also that the great proportion of our medical drugs is prepared from coal-tar products, and these new medical preparations are now numbered by the thousand. The discovery of synthetic indigo from coal-tar derivatives is due to Dr. Baeyer, a German chemist, but it was not placed on the market as an article of commerce until 1897, by the Badische Anilin and Soda-Fabrik of Germany. In the interval between the original discovery of synthetic indigo by Baeyer and its successful introduction to the trade in 1897, color chemists were busy on various lines of work and wonderful progress was made. Among other discoveries, Messrs. Read, Holliday & Sons of England, made the notable discovery of producing fast colors right on the cloth itself. This process was at first confined to the production of a brilliant red, which more than rivalled Turkey red itself. This process in a few years soon embraced several other colors, but the leading color of the group is still this brilliant red, in print-works phrase called ice red, and it has almost completely displaced the genuine Turkey red which has been in continuous use from the remotest ages. The wonderful thing about it is, that whereas the old Turkey red required weeks to produce, the new red, called paranitraniline red, can be produced almost instantaneously. The cloth is simply prepared in a bath of betanaphthol and dried, and then run through a bath of paranitraniline, which is of a buffish color, and in a twinkling the cloth is transformed into a magnificent red. The goods keep passing through continuously all day long, going in at one end colorless and coming out at the other end perfectly dyed a beautiful scarlet. In this way 25,000 to 40,000 yards per day can be dyed. Some precautions are, of course, necessary, such as feeding in the dye liquor regularly; but above everything else it is important to keep down the temperature as near the freezing point as possible by adding ice freely; should the temperature rise a few degrees above 32 degrees Fahrenheit, the dye liquor begins to decompose and will not dye up a full rich color, and if the temperature rises a little it ceases to dye altogether. Note here that with the old vegetable dyes, heat was necessary in dyeing, gradually bringing up the dyebath to the boil. This latter class of colors calls for ice in place of coal.

Another very useful color in this class is called alphanaphthylamine claret, which is very much used. An orange color called metanitraniline orange is also very useful, as it displaces a chromate of lead orange which was a troublesome color. I might name several other colors of this type, but the three named are most in use, and call for precisely the same treatment, and are very reliable.

I come now to the newest thing in the way of colors from coal-tar products, termed indanthrene colors or vat colors because of their similarity in deoxidation and fixation to the indigo vat. For many years a strong prejudice existed against aniline colors on account of their fugitive character; many of them were neither fast to sun nor soap, but it was always felt that the time would come when these difficulties would be overcome. The class of colors just named are absolutely fast and fill all requirements, even of the most exacting nature. Blue was the first color of this group that was discovered, but, as in other instances, it was soon followed by the whole line of shades, and almost the entire body of German color manufacturers have their own special brand of this particular class of colors. For shirtings and wash goods generally these colors supply a long felt want.

This leads me to notice very briefly a very important improvement in the finishing of cotton goods. I refer to seersuckers and various kinds of crepe and crinkled fabrics which used to be produced in the manufacture of the goods and were both expensive and troublesome in the extreme to the manufacturer, and caused much trouble to the finishers of such fabrics.

This class of goods is all made from plainly woven fabrics and the crinkle effected by a chemical process in the finishing. The shrinking of goods by the use of caustic soda was first discovered in 1844, by John Mercer, an English printer, hence the name mercerizing. He used it more particularly for obtaining much brighter colors of greather depth and solidity, but the extra cost of the process and the great loss in length and width by reason of shrinkage led to its abandonment. In 1884 it was again taken up by the French printers, and crimp and seersucker effects produced by printing stripes with caustic soda alone or mixed with colors which were not affected by caustic soda. Such printed stripes, of course, would shrink and cause the unprinted parts to show the crinkle. Now, just the opposite course is pursued; the goods are printed in stripes with plain gum arabic and then run through a strong solution of caustic soda and washed well; the result is the unprinted or unprotected parts are uniformly shrunk up and the stripes protected by the gum arabic show the crinkle.

In Mercer's time, work of this character would have been wholly impracticable, because the vegetable dyes then in use would have been ruined. The use of caustic soda in the finishing of goods had not yet reached its limit. In 1895 Messrs. Thomas and Prevost patented the well-known mercerizing process of running the goods through a strong solution of caustic soda right on to a tenter frame and preventing the cloth from shrinking and washing out the caustic soda before the cloth leaves the frame. This gives the cloth a fine luster like silk which is permanent, and today this process is in universal use.

Elderly Men Still Useful

It seems that the cry "too old at forty," which originated a few years ago in America, no longer holds good. We learn from a New York contemporary that the Employers' Association, Chicago, after comparing the services of a number of men past forty-five years of age with the services of young men in the same work, decided that it is not good policy to count an efficient workman out of the running because he is past forty-five years, and the Association has undertaken to find employment for 2,000 such men.—*The Engineer.*

The Septic Problem in War*

Complicated Conditions Due to a Densely Populated Area

Of all the many varieties of wounds with which surgery has to deal, incised, contused, lacerated, etc., the most dreaded one is the punctured variety. This is because the inflicting weapon is almost necessarily infected with pathogenic organisms, and because these organisms are therefore implanted in the depths of a long and narrow track, into which antiseptics can be made to penetrate only with considerable difficulty.

Of all punctured wounds those produced by gunshots are the most difficult to deal with. The reasons for this become obvious upon consideration. The mere force of impact, in the first place, is an unusual and important feature. The energy in foot-tons of a projectile of known weight and velocity can easily be calculated, and it is to be remembered that this energy is concentrated upon a small area, with the result that the actual track of such a missile in human tissues is a tunnel the walls of which are *dead tissues*.

The importance of this fact in favoring bacterial growth is immense. Moreover, the tunnel is surrounded by a cylinder of tissue of which the constituent elements are bruised and under the influence of local shock, so that their vitality and resisting power to bacterial invasion are reduced. If such a missile strikes hard bone, a high degree of shattering and splintering takes place, while portions of broken bone are driven into the surrounding muscles, sometimes lacerating important vessels and nerves, and even bursting through the skin, and forming a large opening known as an "explosive exit." Owing to the ballistic properties of the pointed bullet, which is now used by all countries, and which tends to turn over on its short axis on impact, the proportion of these severe wounds is somewhat greater than in previous campaigns.

Another difficulty in the case of gunshot injuries is their special liability to severe forms of septic infection in the circumstances of the present campaign. In South Africa military surgeons found that a large number of wounds, even when bone was involved, showed small wounds of entrance and exit, and so far as infection was concerned, merely required cleaning and sealing to heal without trouble. This was in part due to the shape of the bullet and its tendency to traverse the tissues by a straight course without turning on its short axis. This meant small external openings, and therefore less liability to infection from them. But the chief cause of the immunity from infection was the comparative dryness of the country, and a soil for the most part uncontaminated by human occupation or cultivation.

The conditions in the Euroepan area of the present conflict are very different. The humidity of the climate is greatly in excess of that of South Africa, and intensive cultivation means copious manuring of the soil, so that most of the ground occupied by our troops is thoroughly sown with bacteria of fæcal origin, which include, besides those ordinarily called pyogenic or pus-producing, the special germs of tetanus, malignant œdema, and gas gangrene. It is in ground thus infected that our soldiers sleep, take their food, and are occasionally buried alive. The skin and clothes are plentifully smeared with bacterial mud, and it is no matter for surprise that when a bullet passes into their bodies it carries with it, and implants in all the interstices of a deep and complicated wound, the potentialities of a surgical catastrophe.

That the bullet is infected by passing through muddy skin or clothing, often carrying with it portions of the latter, seems fairly certain. Some wounds in South Africa became infected when the bullet passed through the mouth of any part of the alimentary tract, both highly infective regions of the body. The bullet itself, when fired, is probably a fairly clean body from a surgical point of view. The sides are cleaned by the friction of the rifle barrel, and the base is seared by the flame of the explosion. Nevertheless Col. La Garde's experiments have shown that if deliberately infected before firing, it can be shown to be still carrying infection after firing.

The problem, then, which was presented by gunshot injuries was how best to combat sepsis in punctured wounds of all varieties, complicated often by bone injury and severe lacerations of soft parts, the bacterial infection coming usually not from the wound openings, but being deeply implanted by the actual stroke of the bullet as it passed through the tissues. Obviously, the mere application of even the most efficient antiseptics to the parts about the external wounds will not meet such a case. The infection must be attacked in the depths of the tissues, preferably at a very early date after the receipt of the wound, before the bacteria have time to multiply in the tissues. Moreover, practically all wounds of any depth must be dealt with thus. It would be bad surgery to wait until the infection was established, even though few signs of mischief appear at first. Accordingly it was soon recognized that the wound must be opened up, cleaned as far as possible, foreign bodies removed, and free exit provided for discharges by means of drainage tubes.

Some surgeons hoped that in a wound thus opened up, and thereby converted from a punctured to an incised type, it might be possible to remove the infection altogether, and here the advocates of the application of strong antiseptic solutions had their view. A mass infection can be completely destroyed by the application of, say, pure carbolic acid. At a very early stage of infection this may perhaps be possible, but not when the bacteria are in the depths of the tissues. Moreover, it is difficult to reach all the recesses of a large wound, and if one pocket is left unattacked, the surgeon's pains are thrown away. Strong antiseptic solutions, too, are very damaging to the tissues, which, it must be remembered, are in a condition of impaired vitality already. Another drawback to the use of antiseptic solutions, whether weak or strong, is the fact that many of them tend to become inoperative when in contact with the albuminous solutions like blood or pus. They form inert compounds with albumin, and will no longer destroy bacteria. It is claimed for an entirely new antiseptic, called from its color flavine, that it actually proves more formidable to germs when in solution in blood-serum than in aqueous solution. But further trial is required before its value can be exactly classified.

Another device for the early removal of septic matter is to cut away the infected tissues bodily. The extremely localized nature of gunshot injury is a help in this case. It is possible to excise the entire internal surface of the wound *en masse*, with all its sinuosities and pockets, and to sew up the clean cavity remaining. This method enjoys the advocacy of Col. H. M. W. Gray, who has success with it, but to be satisfactory it obviously must be done early, and requires in many cases considerable surgical skill. Cranial injuries and wounds of joints have been treated by this method with an encouraging measure of success.

But both the above methods can be effectively applied only when the wound is seen early, and in warfare this is not always possible. Many hours or even days may elapse before wounded men can be collected and carried to the casualty clearing stations. What, then, can be done when bacteria, deeply implanted in the tissues, are multiplying freely and in circumstances very favorable to their growth? Here the physiologist steps in and reminds the surgeon that the living body has its own guards against bacterial invasion; that healthy blood fluids are inimical to the growth of many, though not of all, bacteria; that the white corpuscles, the so-called phagocytes or germ-eaters, form an immense army for home defence; and that the effect upon the body of the absorption of the special toxins produced by bacterial action is to cause it to elaborate a neutralizing substance or antitoxin. Here, then, is the physiological basis both of the salt method and of the vaccine method of treatment. It is found that if a strong or saturated solution of common salt be applied to an infected wound, the salt by its osmotic action sets up a greatly increased flow of lymph from the tissues into the wound, thus relieving the inflamed tissues of congestion, and setting up a flow of fluid from within outwards which tends to wash away bacteria. Both the lymph and the strong salt solution are unfavorable to the growth of bacteria. So far as the white corpuscles are concerned, strong saline solutions are unfavorable to their vitality; but when the wound has become healthier it is usual to decrease the strength of the salt solution until its saturation has reached that of a fluid of the same specific gravity as the blood. In a fluid of this degree of concentration the phagocytes can live and act freely.

The practical application of these principles consists either in packing the wound with gauze, between the folds of which tablets of salt are placed, or arranging for the continuous irrigation of the wound with a solution of salt of a known concentration. The latter method is suitable in a fixed hospital. And it is one of the great advantages of the former method that a case so dressed often requires no redressing for a few days, so that the anxieties connected with the provision of fresh dressings during transport from the casualty clearing station to the base hospital are set aside. The question of treatment by vaccines can scarcely be efficiently dealt with within the limits of a short article. In any case the rôle of vaccines is to neutralize tissue poisons elaborated by bacteria, rather than to contribute directly to the closing and healing of the wound itself. The ideal vaccine would naturally be one which, injected into the body immediately after the wound is inflicted, has the power of getting in ahead of the toxins and neutralizing them. This prophylactic action is possessed by one of the serums used, and fortunately in the case of one of the deadliest of the bacteria, the tetanus germ. It has been found that the use of this serum in a moderate dose immediately after the infliction of the wound protects the wounded man from tetanus, and consequently an important part of the treatment at the casualty clearing stations is the administration of this preventive dose. As regards the other bacteria, serums and vaccines are used, but their value is not so well established as in the case of tetanus, though important results have been obtained and valuable lessons learnt from their trial.

It will be seen from the above remarks that surgeons had not only to appreciate and elucidate a problem which at first presented many new and puzzling features, but also to devise means for its solution. How far they have been successful cannot be quite known until after the war. But enough experience has been gained to justify the hope that we are on the right track, and that the treatment our brave soldiers have a right to expect can now be given to them.

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